TEA MACHINERY AND TEA FACTORIES

A DESCRIPTIVE TREATISE ON THE MECHANICAL APPLIANCES REQUIRED IN THE CULTIVATION OF THE TEA PLANT AND THE PREPARATION OF TEA FOR THE MARKET

BY

A. J. WALLIS-TAYLER, C.E.

ASSOC. MEMB. INST. C.E.

AUTHOR OF "REFRIGERATING AND ICE-MAKING MACHINERY" "SUGAR MACHINERY" "AERIAL OR WIRE-ROPE TRAMWAYS" "BEARINGS AND LUBRICATION" "MODERN CYCLES" ETC. ETC.

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PREFACE.

SEVERAL very excellent books have been written both upon the Chemistry and upon the cultivation and the Process of Manufacture or Preparation of Tea. As regards the first or chemical aspect of the subject, mention may be made of the work by Mr. Kelway Bamber, and as regards the second of that by Mr. David Crole; but (so far, at least, as the Author is aware) the present is the first work published in book form dealing specifically with the Machinery utilized in Tea Factories, although the manufacture of such machinery has now become an important industry, and one, moreover, which affords a wide field for the exercise of the inventive genius of a large number of engineers.

The Chemistry of Tea is a subject upon which the Author has barely touched in this volume; but with the Cultivation of the Plant, and the process of Manufacture or Preparation of the Leaf, he has been forced to deal to a certain extent, in order to be enabled to describe intelligibly the various machines and apparatus employed. It is to be understood, however, that the main object with which this book has been written is to provide a treatise, and it is hoped a tolerably comprehensive one, dealing primarily and chiefly with the Mechanical side of the question; and that it is in no way intended to take the place of, or in any way to supplant, works now extant upon the chemistry or the cultivation

and process of manufacture or preparation of tea, but rather to form a companion volume to such works.

In the early days of tea planting in the British possessions, little, if any, machinery was employed; but now that it is used in each of the separate operations or stages that go to make up the whole process of the manufacture of tea, and is (or should be) likewise employed in the cultivation of the land, and for transport and other purposes on the plantation, as well as for bulking or blending and repacking in the home warehouse, and for the packeting or parcelling of tea for the retail trade, it has unquestionably become an item of primary importance. The subject of Tea Machinery is, therefore, one which is now of the first interest not only to tea planters, engineers, and inventors, but in fact to every one who is interested in machinery for the cultivation and manufacture of tea, as well as to those who have the subsequent handling of the finished product.

These several classes of the community form together a sufficiently numerous body to warrant the belief that the present volume will meet an actual want, without taking into account the fact that the matter is one of general interest to engineers, students, and many others.

In dealing with the subject, the Author has elected to treat it from a practical or common-sense point of view rather than from a theoretical one, and has endeavoured to be as concise as should be consistent with intelligible description, and to include as much and as recent information as possible. Besides the more lengthy disquisitions which are given upon the machinery and apparatus in most general use, for the benefit of those who may be thinking of patenting or endeavouring to devise some improvements in this class of machinery, short descriptions are also given of a large number of other machines and apparatus, thereby enabling any such inventors to obtain, with a minimum amount of labour, a fair idea of what has been already done in this direction.

It may be here remarked that the "patent" aspect of the

question is one of very considerable importance, as the number of machines protected by letters patent is large, and the law courts of both India and Ceylon have witnessed numerous disputations concerning alleged infringements.

An endeavour has also been made to render the classification and description throughout as simple and as clear as possible. With this object in view, the book has been divided into seventeen chapters, the first of which treats of the mechanical cultivation and tillage of the soil; the second, of various methods of plucking or gathering the leaf; whilst the ten next succeeding chapters are devoted to descriptions of the factory and of the various machines and apparatus employed therein. Two following chapters deal with the means of transport on the plantations; one chapter is taken up with the miscellaneous machinery and apparatus used in and about tea factories; another is given over to machines for the final handling of the tea, such as mixing, blending or bulking machines, and packeting or parcelling machines; and finally, the last chapter contains a number of tables and memoranda pertinent to the subject, and likely to be found useful by those engaged in the industry. The subject-matter is, moreover, profusely illustrated, most of the blocks used having been especially drawn and engraved for the work.

In order to make the book as useful as possible for purposes of reference, an exceptionally full index has been appended, and a very large number of cross-references have been introduced into it—a feature which will greatly facilitate the labour of tracing information on any particular subject dealt with in the volume.

The tendency lately shown by the public—whose taste is ever fickle—to revert to Chinese teas, coupled with the certainty of the increasingly severe competition which must inevitably result in the near future from over-production (due not only to the extension of the area under cultivation as tea gardens in India, Ceylon, Natal, and other British possessions, but also to the development of the industry in the United States and elsewhere),

renders it doubly important for the planter to have the advantage of a properly-laid-out factory, thoroughly well equipped with the most efficient machinery it is possible to procure, as well as to have the best facilities for transport on the plantation. These considerations should tend to greatly enhance interest in the subject at the present time.

It should also be remembered that, whilst the possession of a good plant of machinery, and of a well-designed factory, will enable good tea to be made from an inferior quality of leaf, on the other hand, a good jat, suitability of soil and climate, and the most efficient possible cultivation, will all be thrown away if such means are not at hand to facilitate the preparation or manufacture of the tea from the green leaf.

In conclusion, the Author begs to express his obligations to the various manufacturers and others who have courteously afforded him information and assistance in the preparation of the volume, as well as the hope that the book will be found to have fairly attained the end he has had in view, and may thus prove of substantial service to those for whose use it is more particularly intended.

ALEX. J. WALLIS-TAYLER.

MANCHESTER
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TEA MACHINERY AND TEA FACTORIES.

CHAPTER I.

MECHANICAL CULTIVATION, OR TILLAGE OF THE SOIL.

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INTRODUCTORY.

ASSUMING the best jât or type of tea plant, the most suitable description of soil, the proper elevation, and the most appropriate climate, to be points already satisfactorily settled, there still remain two matters of the greatest importance, the neglect of which will prevent the best possible results being secured from a tea plantation. These are, the suitable cultivation or tillage of the soil, and the provision of a properly-constructed and located factory replete with first-class machinery and appliances for the dressing, manufacture, or preparation of the leaf.

At the present time all these requirements usually receive a very considerable amount of attention with the exception of the cultivation or tillage of the soil, which latter is even now, in the vast majority of instances, still carried on by hand in the old and inefficient manner, and that although there can be no question but that good tillage with suitable manuring would result in an increase both in the quantity and quality of the product.

The tillage of the ground for the preparation of land for the planting out of new gardens, and for the after-cultivation of the tea plants, is, as above mentioned, at the present time practically universally carried on by hand labour, and consists of hoeing, digging with forks, and weeding by hand. To a very limited extent indeed, tillage by means of crude local ploughs, and by light Ransome ploughs, has been used, on a certain number of plantations, instead of hoeing or digging, but the latter methods are as yet the chief means of cultivation adopted in India and Ceylon.

The present practice, when laying out new plantations, is, after the land has been properly cleared, to have the ground deeply dug up with hoes. As soon as the planting out of the seedlings has been completed, the plantation is divided up into sections of varying size, according to the taste or fancy of the planter, or to the exigencies of each particular case, but being usually something between five and ten acres in extent, by roads or paths, and drains (nullahs) are dug between the rows of tea plants at distances apart of from eighteen to forty feet: these latter, as well as the necessary large or main drains, having naturally to be adapted to suit the class of soil, locality, greater or lesser liability to floods, &c., any rigid rule upon the subject would be obviously impracticable. The branch drains, however, are generally about three feet in depth by about nine inches or a foot in width, and the main drains about five or six feet in depth, by a width at the bottom of from nine inches to a foot, and at the top from eighteen inches to two feet. At the present time this drainage work is invariably executed by means of hoes, or other hand implements, and is, as may be easily imagined, about the hardest work connected with the preparatory cultivation of the ground for the growth of the tea plant.

The after-cultivation of the soil consists in frequent hoeings to keep down the weeds, this operation being required about once every month, or even oftener in some months. When the soil is of a light or friable nature, the fork may be with advantage substituted for the hoe, and in any case such soils require less hoeing than those of a heavier nature, and the addition of organic matter in some suitable form, so as to produce the necessary amount of nitrogen for the nutriment of the tea shrubs. The soil is

usually double-hoed in the cold season, and it is advisable after that operation to leave the ground in a rough state.

The prunings of the tea plants are, as a rule, hoed in; only light prunings, however, should be so dealt with in the case of the double hoeing executed in the cold weather. The weeds round the stems of the tea shrubs are always pulled up by hand, and hand weeding is frequently entirely resorted to on hill plantations, as it prevents the large loss of the surface soil which would otherwise take place during the heavy rains, where the ground was hoed or dug.

Mr. Christison states that the result of his experiments in Darjeeling with rough and thorough cultivation, on equal plots alongside, carefully noting the result as to benefit derived from dew and retention of moisture, left no doubt as to the immense advantage of the latter system over the former.

Cultivation by means of the straight digging fork is found to be safer in hilly districts as being less likely to injure the roots of the plants, than the native hoe or kodalie.

The same authority recommends for the second and succeeding cultivations at the close of the spring and the early part of the tea season, hand weeding as being the most suitable and stimulating culture of all. By disposing of the weeds or grass in layers or bands across the slopes the waste can be checked most effectually, even where there are no terraces.

Experiments as to the practicability of tea growing as an industry in the southern districts of the United States have been carried on for many years past, but the cost of labour and the deficient rainfall have hitherto rendered them more or less abortive. Dr. C. U. Shepard has at length, however, succeeded in establishing a tea plantation at Pinehurst, Summerville; S. C., and in making a practical commercial success of the undertaking; and as this result is said to be due to the method of cultivation adopted, a short account of the latter will be of interest.

About fifty acres are, at present, set in the tea gardens, which are in a noticeably high state of cultivation. The chosen site for the initial garden was an old piney woods pond, with its black, rich (in humus) but sour surface soil overlying quicksand and a substratum of clay. This ground was thoroughly subsoiled, drained, and heavily sweetened with burnt marl. It was

afterwards ploughed deeply, followed by a subsoil plough stirring up and pulverizing to a depth of eighteen inches or more. In preparation for the garden, the seeds, when received from the Orient, had been at once sown in beds of light fibrous soil and sheltered from the direct sun, the native habitat of tea plants being an undergrowth in shady forests. In a few months after the soil treatment about one thousand seedlings of the acclimated Assam-hybrid tea were set out six feet by six feet quincuncially, and shaded on the south-west side by the insertion of a broad shingle.

Considerable slowness was shown in the early growth of the species (which resembles in this respect its relative the *Camellia japonica*), attributable possibly to the necessity for overcoming the original acidity of the soil. Delay was also occasioned by the erroneous plan of pruning, following the foreign practice and adopted at the beginning, whereby clean stems were maintained, and the loss of many plants resulted. The production per bush has since been almost five ounces of finished tea, which equals the best yield per bush of Ceylon and India, and is from two to five times the average yield of China and Japan. This excellent result of an experimental tea garden presages final economic success, and attests the wisdom of the methods of cultivation adopted by the grower. Two larger gardens, also formerly piney woods ponds, are planted with Darjeeling seedlings, and promise successful rivalry within a few years; and yet others give token of still greater productiveness.

The experience gained shows that the main points to be observed in cultivation inhere in the method of pruning; first directed to the gradual extension of the breadth of the plant, thus increasing the number of shoots available for picking; and second, to strengthen these shoots, so that their vigour may be maintained up to the last flush, and they are able to react quickly in fresh delicate foliage. Both scientifically and economically, this has been found to be better than the plan pursued in India (of a single severe pruning every fourth year and a rest the year following), as there is no depreciation in the strength of the plant, and no loss of crop entailed.

The success of the experiment has further depended on the selection of plants that will produce fine tea and yet withstand frost, seeds from the higher grades of Ceylon and Assam being

too tender, whilst the older varieties of the plant produced in China will endure a temperature as low as twenty-five degrees. The most promising variety, combining hardiness with a good-sized delicate leaf, is found to be that brought from Darjeeling, grown at an elevation of 3,000 feet.

By means of draining in connection with deep soil cultivation, a more ample and lasting supply of moisture has been secured for dry times. This conservation of moisture is also furthered by a careful system of surface culture which greatly prevents evaporation from the upper stratum of soil. A gain equivalent to a fall of ten to fifteen inches of rain has thus been secured, and tea growing made possible in any region where the yearly rainfall equals fifty-six inches. This latter result is of great interest when we consider that Asiatic authorities assert that from eighty to one hundred inches are essential, and that the greater precipitation should come in the early part of the year, some of the best tea districts having 120 inches of rain per annum.

Cultivation by Steam Power.

There can be but little doubt that much of the cultivation of tea plantations in the plains districts could be performed with great advantage by means of agricultural machinery, which need not differ to any material extent, if at all, from that used upon large farms in this and other countries.

There is no more excuse for the continuation to employ the old system of cultivation by hand labour, which is only rendered possible, indeed, by the low wages paid in tea-growing countries, than there would be for persisting in the use of the old primitive hand methods of dressing or manufacturing the leaf.

An additional incentive to the employment of machinery is that whilst some crops oppose considerable difficulties to mechanical cultivation, the tea plant, on the contrary, seems to lend itself in every way to that method.

Steam cultivation, which of course would be the form most advantageous for employment on tea plantations, has now been so much simplified and perfected that its successful application in the major number of instances would offer no difficulties.

Three systems of cultivation have withstood the test of practical

work extending over many years, and are at present in common use, viz., the double engine system, the double drum system, and the roundabout system; but of these the first only has proved itself capable of being successfully worked under practically every condition of country, climate, and soil, and consequently is the one, in the author's opinion, which would be most suitable as a general rule for use on tea plantations.

As each of these systems, however, has determined peculiar advantages which render it more desirable for special application under certain specific conditions, a short description of all these will be given, but before doing so it will be well to mention the most essential principles to be sought for in any system which it is proposed to adopt, if the utmost economy and efficiency of working is to be obtained. These principles are:—

First, a direct pull upon the implement without the interposition of pulley or snatch-blocks.

Second, the use of the shortest amount of wire-rope possible.

Third, the utmost facility of moving the machinery to and from its work practicable.

And fourth and lastly, the necessity for the employment of only a minimum amount of auxiliary manual and animal labour.

The Double Engine System.

The double engine system is worked by means of two traction engines fitted with horizontal winding drums and automatic coiling gear moving along opposite headlands, each engine alternately hauling the plough, or other implement for cultivation, towards itself, whilst the engine not in work pays out the rope, and, at the same time, moves forward to take up the proper position for effecting the return journey of the cultivating implement.

It will be seen by the above short description that in this arrangement no fixtures on the land are required, and that the tackle can be set to work with the greatest facility. As the engines, moreover, are ready to travel the moment that they stop hauling the cultivating implement, they can move themselves and the implements, together with a supply of fuel and water, without the assistance of manual or animal labour.

The Double Drum System.

The double drum system is undoubtedly the next most successful to that first-mentioned; it is worked by means of one traction engine, in combination with two horizontal winding drums travelling on one headland, and with an automatic self-moving anchor travelling on the opposite headland. The engine works along the side of the land, directly opposite to the self-moving anchor, and is so constructed as to effect a pull directly upon the implement as in the first or double engine system. The entire apparatus required for this arrangement consists of a double drum engine, an efficient automatic self-moving anchor, corner anchors, and snatch-blocks, and rope porters, and, of course, the necessary amount of wire-rope.

The Roundabout System.

The roundabout, or last of the three systems mentioned, is that which has met with the least measure of success, and it is, indeed, only applicable with comparative advantage on estates of restricted area, and which, moreover, have been especially laid out to suit it.

The work is effected by one traction engine and a windlass, and two automatic self-moving anchors travelling on the two opposite headlands of the field. The entire tackle comprises either a portable engine or a traction engine, a detached windlass with two horizontal drums fitted with automatic coiling gear, two automatic self-moving anchors, four claw anchors, the necessary amount of wire-rope, two large rope bearers or porters, and an universal driving joint, or a belt to transmit power from the engine to the windlass.

This last system was at one period considered to be the most successful way in which the cultivation of land could be effected by steam power, but it has now, for some time past, been almost completely superseded by the first two methods. The system has, however, the merit of being cheap.

Arrangement of the Double Engine System.

In Fig. 1 is illustrated a view of an arrangement of Fowler's[1] patent double engine system of steam cultivation, which has been

[1] John Fowler & Co. Ld., Leeds.

reproduced from a photograph of the apparatus when actually at work in the tropics, and this system being, as has been already mentioned, in the writer's opinion, the one best adapted for use on tea plantations, will be described in detail.

The traction engines shown in the illustration are of the type drawn to a larger scale in Fig. 2, and especially constructed for use in tropical or other warm climates, and are in this instance each fitted with a fuel-feeding apparatus, grate-bar arrangement, and baffle-plates, suitable for burning straw, cotton, maize stalks, reeds, sugar-cane, megass, and other vegetable refuse as fuel where coal or wood is not readily procurable. For localities, however, in which there are plentiful supplies of the latter fuels, the above apparatus can be removed, and an ordinary set of fire-bars substituted for the special ones.

The chimney is of the American spark-arresting type, and a light roof is erected over the footplate to protect the driver from the sun.

Fig. 2 shows one of these engines in side elevation, from which view it will be seen to be a combination of a traction and of a winding engine. The construction of the engine is remarkable for its simplicity, and the ease of access of all working parts, which, it is hardly requisite to remark, are most important features in an engine intended for use on a plantation necessarily at a long distance from engineering establishments. The link motion and reversing gear is of the ordinary locomotive type, all the joints and wearing surfaces being made extra large, and the levers, clutch gear, brake, and steerage gear being all arranged so as to be within easy access of the driver. The engine is of the compound type, and the starting of it is greatly facilitated by the provision of a valve which admits of live steam from the boiler being supplied to the low pressure steam chest, so that the normal power of the engine can be considerably increased for a short time whenever required. This valve is so arranged as to be worked quite independently of the regulator lever, and to close automatically the instant the operating handle is released, and thus to prevent any unnecessary waste of steam taking place.

The proportion of the cylinders is such that the work performed will be divided between them, and the power is taken off by

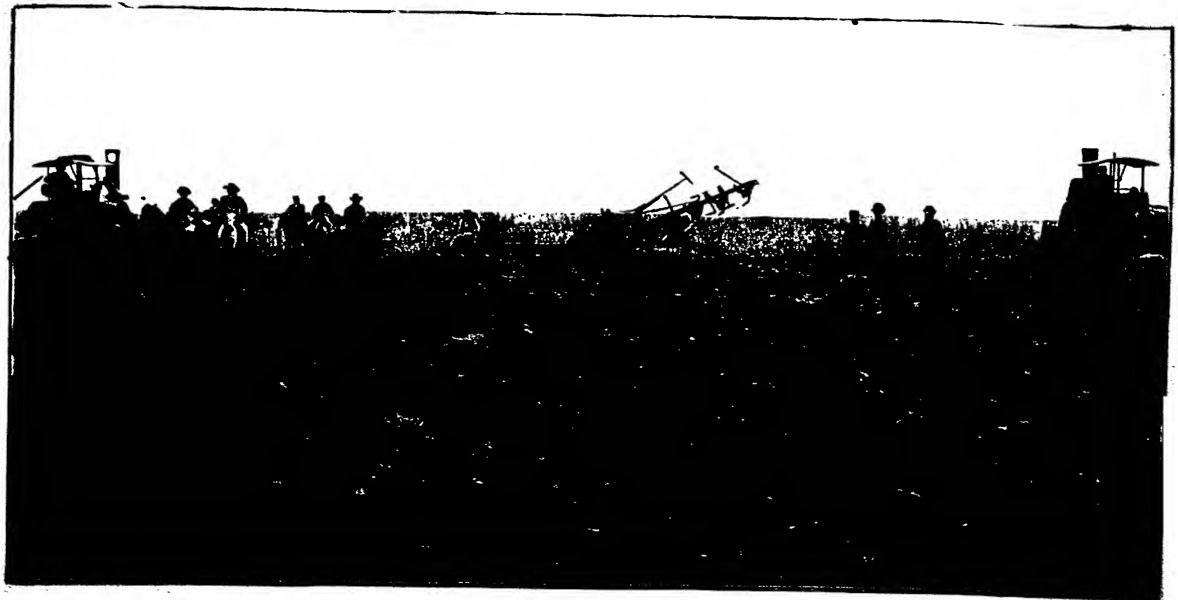


FIG. 1.—Double Engine System of Steam Cultivation.

double web-balanced cranks set at right angles to each other, thereby insuring great steadiness in running, obviating jerks and

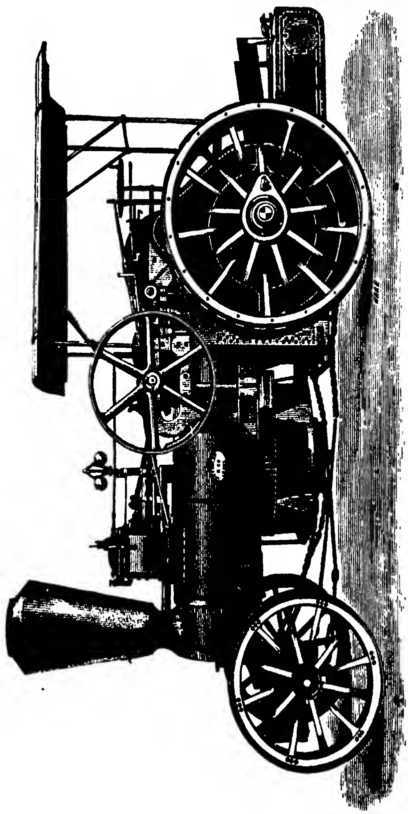


FIG 2 —Ploughing or Cultivating and Traction Engine

shocks, and rendering the strains upon the shafts and gearing more equable.

As there are no dead centres, the engine can be reversed at any

moment without pulling over the flywheel or suddenly reversing, as is necessary in the case of single-crank engines.

The boiler is entirely constructed of the best Siemens-Martin's steel plates, carefully annealed and planed on the edges. The flanging of the plates is done by hydraulic pressure, and the rivet holes are drilled in position after the boiler is plated together, the double riveting being effected by hydraulic pressure. The usual manhole is provided for inspection and cleaning, and mud-holes are arranged at the bottom corners of the fire-box shell, thus giving direct access to the water space on all four sides; it is also suitably lagged with asbestos packing. The boiler is tested with cold water up to 260 lbs. per square inch, and is adapted for a working pressure of 180 lbs. per square inch, being thus equal in strength and workmanship to one of the best locomotive boilers.

The travelling or road wheels are constructed of steel and wrought iron, and have a width of tread of from sixteen to thirty-six inches in accordance with the nature of the ground they are required to work on. The road gear is entirely made of the best crucible cast steel. The road motion is provided with two speeds, the faster one for use on hard land, and the slower one for travelling over soft and uneven surfaces, and in like manner the ploughing gear can when required be fitted with two speeds, viz., a slow speed for heavy and a fast speed for light work.

The necessary power is transmitted from the crank shaft to the winding drum by means of a vertical shaft and bevel, or mitre, and other toothed-gearing.

The winding apparatus comprises a horizontal drum, capable of carrying 450 yards of steel wire-rope, and it is fitted with a patented arrangement for coiling, which automatically winds, unwinds, and coils the wire-rope uniformly. This gear has a self-acting coiling arm which carries two adjustable guide pulleys, and has a vertical movement, being thus free to swing or move round the winding-drum into any position at which the rope has to pay off, thereby avoiding to a great extent the undue strains or jerks on the rope and on the apparatus, which are otherwise unavoidably experienced.

It is obvious, of course, that one of these engines when not employed as a self-moving cultivating engine can be used as a traction engine for hauling purposes on ordinary roads, or for

pumping, grinding, sawing, or any other duty in which the power can be transmitted by belt gearing. This system allows of a far larger day's work being effected than can be done by means of either of the two others, and it is peculiarly suitable for the cultivation of light land. From thirty to fifty acres can be dealt with daily, according to the nature of the soil, &c.

A further advantage of the double engine system is that it can be advantageously employed for the clearing and reclamation of land, the hauling ropes being available for removing roots, rocks, trees, &c., thus rendering the tackle very useful for preparing the land for the laying out of new tea plantations, as well as for their future cultivation.

IMPLEMENTS FOR STEAM CULTIVATION.

With respect to implements for the clearing and reclamation of the land, Fig. 3 illustrates a patent reclamation plough made by

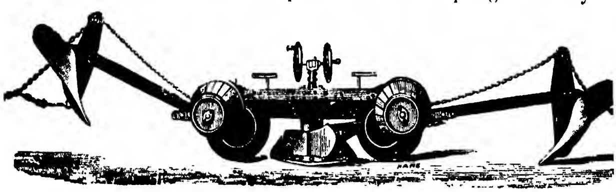


FIG. 3.—Reclamation Plough or Implement.

John Fowler & Co. Ld., which is known as the Sutherland, and Fig. 4 shows a patent balance grubber and knifer constructed by the same firm, which is of an extra strong pattern, and suitable for reclamation work up to thirty inches in depth, being especially suitable for removing stones or tree roots.

As regards the after-cultivation of the tea plantations there can be no doubt that the experience which would be gained after a few years' practical work would result in the design of special forms of implements peculiarly suited for the work. At the present time, however, dealing with such implements only as are now in use, in the author's opinion, founded upon experience in land cultivation on an extensive scale in tropical and other countries, a patent turning cultivator such as that shown in

Fig. 5, and a patent medium cultivator such as that shown in Fig. 6, would be found to be the most suitable for the purpose.

The powerful cultivator shown in Fig. 5 consists of a strong iron frame which can be arranged to work with any suitable number of tynes up to the maximum number which it is adapted to carry, for instance, from five to thirteen tynes. It is supported on three road wheels, the single front wheel of the set being flanged and used for steering purposes. The medium cultivator shown in Fig. 6 is constructed in three pieces, so as to admit of its accommodating itself to uneven surfaces, and it is adapted for light cultivating work.

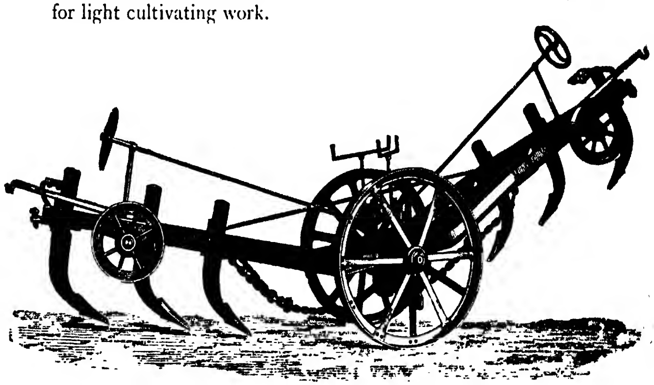


FIG. 4.—Extra strong pattern of Balance Grubber and Knifer.

Where ploughing might be found to be the most suitable form of cultivation, the four-furrow Fowler patent Cuban balance plough, shown in Fig. 7, or the five-furrow Fowler patent Cuban anti-balance plough, fitted with skimmers, shown in Fig. 8, would in all probability be found to be the most desirable types, in the absence of a pattern especially designed to meet the exigencies of the particular locality, such as the general formation of the country, its condition, and special requirements, the nature of the soil, and other items which might demand modifications of more or less importance.

The patent anti-balance gear fitted to the latter plough would form a very advantageous addition to all ploughs intended for

light ploughing, as its action overcomes the tendency which the plough otherwise has when ploughing shallow to jump out of its work, and it produces a level sole.

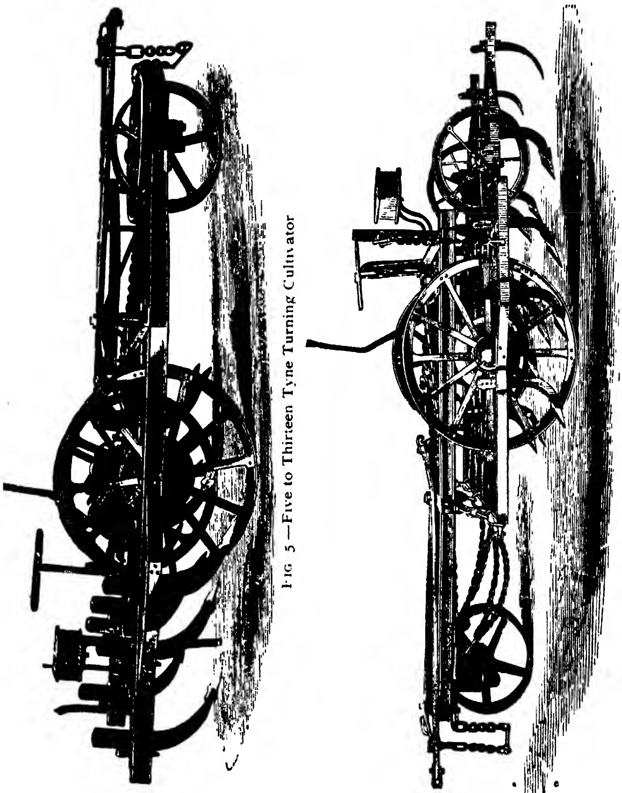


FIG 5.—Five to Thirteen Tyne Turning Cultivator

This arrangement, which is illustrated in Figs. 9 and 10, is as follows: When the plough is on the balance the axle with the travelling wheels is on the centre line of the plough, as shown in Fig. 10. Instead, however, of the axle being fixed in this

position, and the plough balancing upon it, the axle is fitted with two pinions, which travel in a rack path extending some distance to either side of the centre line of the plough, the path inclining from the centre line at the same angle as the opposite portion of the plough.

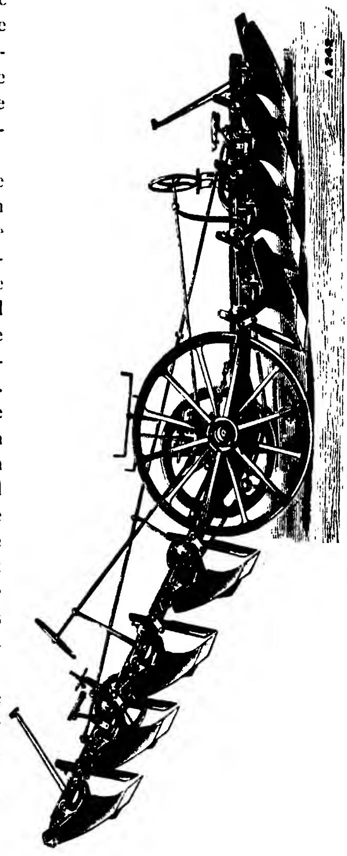


FIG. 7.—Four-furrow Cuban Balance Plough.

On the centre of the axle is a lever to which the hauling ropes are attached, and the pulling strain causes the axle to revolve, and thus travel in the one or in the other direction along the rack. Thus, if we assume the plough to be on the balance, in which position the axle will correspond to the centre line of the plough, any strain put upon the hauling rope will make the pinions of the axle travel towards the forward end of the plough, and the front portion of the latter will be raised and the balance overcome. A pull on the hauling rope in an opposite direction, on the other hand, will exactly reverse this operation. For example, upon the plough reaching the pulling or winding engine the axle will be in the position shown in the illustration Fig. 9, wherein the plough

is depicted as ready to start working. Upon the other engine then beginning to pull, however, the axle will travel to the centre of the plough, where it lodges in a recess, and the plough will be balanced, and can be swung into new land, in the usual manner. The pull of the rope when starting the plough into work will then cause the axle to leave its recess and to travel forward to the end of the rack, thereby again throwing the plough out of balance, in which condition it will remain until it reaches the pulling or winding engine on that side, and so on *ad infinitum*.

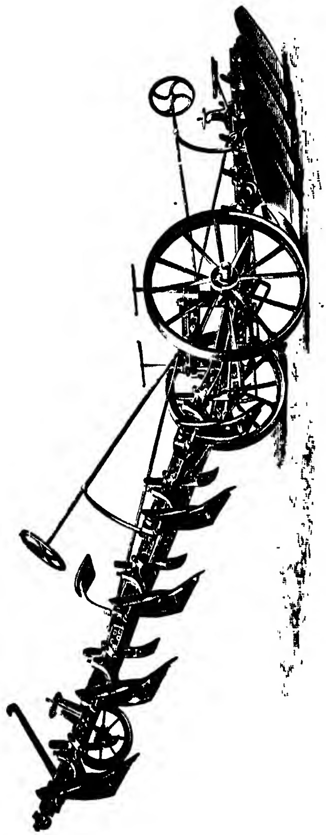


Fig. 8.—Five-furrow Cuban Anti-Balance Plough fitted with Skimmers

Draining and Ditching Machines.

As has been already observed, one of the, or rather the, severest of the tasks that have to be performed on tea plantations is that of draining, carried out as the operation so universally is, by means of hoes. It is likewise a work of great importance, as without a proper system of drainage failure is a foregone conclusion, the presence of any stagnant water in the soil being absolutely fatal to the successful

growth of the tea plant. Of course, the drainage will have to be suited to the class of soil, but little, or comparatively little, being required where this is of an open friable nature, with a free porous subsoil, and situated at a pretty high elevation.

When choosing the site for a new plantation it is always necessary to see that there is a possibility of obtaining a proper fall for the drainage-water.

As has been already observed, the distance apart at which the branch drains in the plantations should be located, will vary from eighteen to forty feet, in accordance with the nature of the soil, and the most usual depth is one of three feet, this latter being found to be that which is about the most convenient in practice;

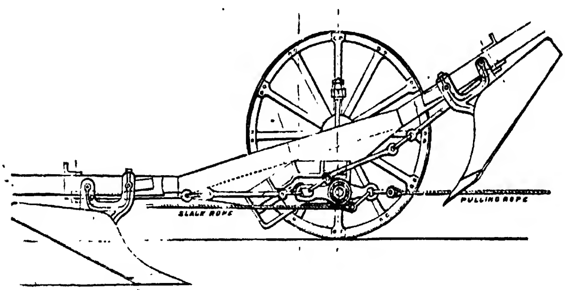


FIG. 9—Anti-Balance Gear Plough in Working Position

it is, of course, obvious, however, that the deeper they can be made in reason the better.

It is advisable, or, rather, absolutely necessary that the branch drains should be arranged to open into the main drain at an angle—that is to say, that they should be taken into them as much as possible in a direction corresponding to that of the flow of the main drain; and, of course, care should be taken that the opening of the branch drains on contrary sides of the main drain be not located opposite to each other. At least every year the drains should be freed from weeds and deposits.

Not the least advantageous application of steam cultivating machinery to tea plantations would be the formation of the drains, and the periodical clearing out of them afterwards by means of a

suitable ditching and draining machine. In the case of drains required to be of a depth which could not be excavated by one of these implements, the additional depth required could be executed by hand in the usual manner.

Fig. 11 illustrates a special ditching and draining machine designed and constructed by John Fowler & Co., Ld. This implement is fitted with a centrally-arranged coulter, by which the mass of earth to be removed will be split or divided into two halves or parts, being then conducted upwards and deposited on both sides of the finished ditch by two long suitably-shaped mould boards.

The implement can be let in and lifted out of the ground in the following manner, that is to say, the axle of the rear wheels is

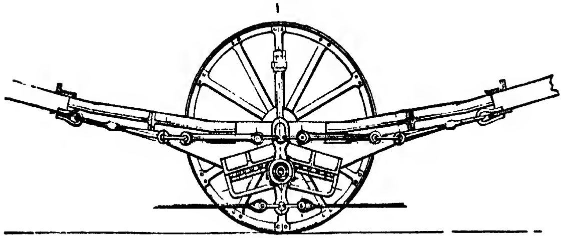


FIG 10—Anti-Balance Gear. Plough Balanced in Central Position.

cranked, as shown in the illustration (Fig. 11), the result of this arrangement being that in rotating this axle the wheels will be pressed down or lifted up, and consequently the frame of the machine will be also either raised or lowered.

Near the front end of the frame and just behind the fore or steering wheels is mounted a rope sheave, around which the wire hauling rope from one of the ploughing engines is passed or reeved, the other extremity being firmly secured to one of the rear wheels of the same engine. By this means it will be seen that the strain exerted by the pulling or winding engine will be doubled.

A ditching and draining machine of the type which has been just described, but of extra strong build, is shown in Fig. 12, as it appeared when in the act of excavating a drain, and as the illustration is a direct reproduction of a photograph taken of

the implement when actually in operation, it necessarily shows in a remarkably clear and truthful manner the way in which it performs its work.

A pattern of ditching machine which can if desired be operated by animal power is made by the F. C. Austin Manufacturing Co., Harvey, Chicago, U.S. When animal power is used six teams and three men will be required, and this machine is capable of handling 1,000 cubic yards of earth in a day of ten hours.

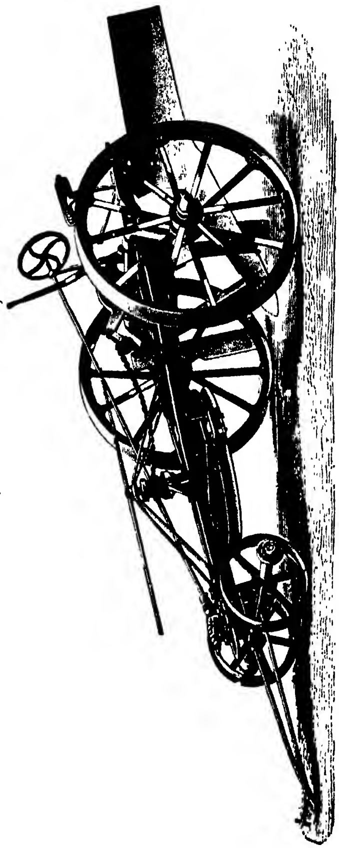


FIG. 11.—Steam Ditching and Draining Machine.

In using steam cultivating machinery of all descriptions it is advisable not to let the hauling ropes come in contact with the ground, and in order to prevent this, devices which are usually known as rope porters, and two forms of which are shown in Figs. 13 and 14, should be employed to support the rope wherever this is likely to occur. They consist, as will be seen from the illustrations, of suitable sheaves mounted at right angles to the frames carrying the wheels, three of these latter being

provided to each frame so as to admit of their being moved sideways by the rope.

Propagation of the Tea Plant.

Although the machinery and apparatus used in the cultivation and manufacture of tea forms the main subject of this present work, this chapter could hardly be intelligibly concluded without a few remarks upon the propagation and planting out of the tea plant, and upon the most suitable soils and manures, or fertilisers, for its growth; consequently no apology is needed for this slight digression.

The tea plant is propagated by seed, which method results in there being numerous slight varieties found amongst the seedlings, and causes a plant of a superior quality to be obtained from the same kind of seed when grown in a district where the climate and soil are both specially favourable, and which seed, in other localities, would only have produced plants of an ordinary description.

The obvious lesson to be acquired from this is, that only such seeds and young plants as have been obtained from the best and most favourably situated districts should be used for new plantations; indeed, most tea planters of experience always prefer, when laying out additions to their plantations, to procure the seed from a distance rather than in the direct vicinity.

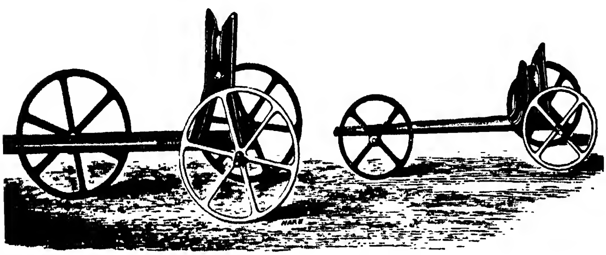
In India the most superior quality of seeds are said by Mr. David Crole to be procurable in Upper Assam and Manipur, from such plantations as Singlo, Taukok, Bazalona, Jaipore, and Tingri, &c.; the best description of seed being that procured from trees denominated indigenous once removed, that is to say, the product of a seed-garden which had been planted with seeds produced in a pure indigenous seed-garden; and considerable profits are made from the sale of seeds by such gardens as have acquired a name for the production of qualities which are characterized by both purity and hardiness. Mr. Geo. W. Christison is of opinion that a blend from China and hybrid plants, or the best varieties of the China plant, are to be preferred, especially on high elevations, and will yield tea of the choicest quality.

Seed-gardens are, as a rule, situated in portions of the estate remote from the other tea, and they are not unlike orchards in

Fig. 12.—Large-Size Steam Ditching and Draining Machine at work.

appearance. The soil of a seed-garden is not required to be so rich in organic matter of a nitrogenous nature as is desirable for other crop growing; the cultivation, however, should be deep, and the ground be thoroughly freed from stones and well-manured, common salt and magnesia being recommended for the latter purpose. The plants should not be crowded, and only the surplus wood and rotten parts should be removed by pruning. Root pruning is also said to be beneficial when judiciously carried out.

The seed commences to ripen in September, and should be harvested as soon as it is fit for picking, and the good seed is usually separated from the bad by throwing the lot into water,



FIGS. 13 AND 14.—Rope Porters or Supporting Devices

when the heavier portion, which sinks to the bottom and consists principally of good seed, is taken out and dried, whilst that which floats on the top of the water is discarded as being worthless.

This water test is, however, far from being a complete one, as the floatage sometimes germinates well, and sunk seed may not—perfectly rotten seed sinking to the bottom of the water.

In the case of imported seed, some hundreds of them should be broken, and the germ examined under the microscope with great care, for although the kernel may look sufficiently sound, a sloughy appearance of the germ means that it has perished, and will not germinate.

The seeds must be germinated before sowing in the nursery beds. This germination is best effected between layers of wet river sand, in a place protected from light, the seeds being turned over and watered, and examined periodically, and when found to

be sprouted, taken to the nursery beds and planted out. The loss by failure, in the case of seed of good quality, is generally guaranteed not to exceed 10 per cent., but with the best kind of seeds the failures are frequently found to be as low as 2 per cent. The greater the doubt about the seed the thinner and fewer should be the layers, because deep pits and heavy layers cause fermentation, and hence rotting.

The nursery beds should be about six feet in width, and separated by shallow trenches, and the soil should be well dug or hoed up, broken up fine, and all roots, &c., removed.

A convenient method of planting out the germinated seeds sometimes adopted, is by means of a board of considerable length, having holes at a suitable distance apart. This board is used as a sort of template, by placing it on one of the beds and alternately forming a hole in the ground by means of a dibble stick, and planting one of the germinated seeds in each of them. When a germinated or sprouted seed has been dibbled into the bed through all the holes in the board, this latter can be moved further on, and so on until the whole of the bed has been planted, when the bed should be well watered, and so covered as to protect it from the sun, the protective material, however, being removed directly the young plants begin to sprout above the ground. The best distance apart, according to Mr. Christison, referring to Darjeeling practice, is four inches by four inches, which, after the early and first season's operations thinning out, will afford sufficient space for the remaining seedlings.

The nursery beds should not be located at any great distance from the new ground to be planted out, and should be well protected from both sun and winds, and a low position in the vicinity of water is considered the best.

As regards soil, a loam sufficiently stiff to adhere to the roots of the plantlets, and with an open subsoil, is preferred, good drainage and cultivation being, of course, a *sine quâ non* if healthy seedlings are to be obtained.

It will be understood that the nursery beds must be always thoroughly well fenced in, so as to render the trampling of them by cattle and other animals impossible, or very difficult, a precaution which, it may be mentioned, is likewise necessary with respect to newly laid-out plots.

This fencing is usually effected with barbed wire, and rows or lines of strong posts firmly set in the ground.

The land intended to be laid or planted out with tea must be first of all staked out (having been, of course, already properly cleared and dug or hoed up, or prepared for their reception, either by hand labour or by steam power), to indicate where the young tea plants or seedlings are to be set. This operation is usually performed in British gardens by means of a chain marked off at regular intervals, by which marks the stakes are set, the usual distance apart of these marks being about four feet. As regards the most advantageous distance to leave between the plants, however, a considerable amount of difference of opinion exists amongst various authorities. For the hills Mr. Christison recommends five feet by four feet; four and a half feet by four and a half feet; or four and a half feet by four feet.

When the cultivation between the rows is effected by ploughing or grubbing the distance should be somewhat greater, in order to prevent the lateral roots of the tea plants from getting damaged, and the cleaning close to the stems should be performed by hand.

Two methods of planting the bushes are now principally in vogue on Indian plantations, viz., the rectangular and the triangular: in the first the plants are so placed as to form the four sides of a series of squares, being thus in line in a direction perpendicular and parallel to the base; whilst in the triangular system they are so planted as to form the extremities of the base and the apex of a series of triangles, and are consequently only in line in directions diagonal to the base.

In former times the plants were universally set out without any attempt at regularity. Sowing together in rows, scattering broadcast, and the like, are now things of the past, but even at the present day the tea seed is sometimes sown directly in the ground to be laid out as a tea garden, instead of being first sown in nursery beds and afterwards transplanted to the garden. This method, which consists in sowing three seeds round each stake, is not, however, found to give as good results as when the plants are transplanted from a seed or nursery bed, inasmuch as the plants do not, as a rule, thrive so well, or grow into such strong bushes subsequently.

With respect to the relative advantages of the square and

triangular methods of planting out, opinions of experts seem to differ somewhat as to which is the most desirable one to adopt.

The square seems, undoubtedly, to be the cheapest in first cost, but the triangular admits of a larger number of plants being got into a given area. This latter point, however, is not one of any great importance so far as the saving of the value of the land is concerned, inasmuch as tea plantations are, as a rule, located in countries where the price of land is almost nominal, but it also effects a considerable reduction in the constantly recurring expenses of cultivating a given number of plants; the last, or triangular plan, enabling about 15 per cent. more plants to be set in any particular area, thus, of course, considerably increasing the crop obtained from it. Some authorities, with every appearance of reason, give decided preference to the triangular system of planting, contending that the plants obtain all the nourishment necessary, and that the surplus space in the square method is practically wasted, and contributes but little, if at all, to the nourishment of the plant; whilst the small extra cost of setting would be repaid many times over by the subsequent saving effected in the expense of cultivation, which latter is, of course, the main item on a tea plantation.

Whatever the system of planting out that may be adopted, however, the strictest care must be taken to properly set the young plants, in order to avoid the loss arising from the large percentage of them which would otherwise perish, and the consequent trouble and expense of planting in fresh ones to replace the latter.

The seedlings are usually dug from the seed or nursery beds by means of a species of iron-shod stake, known as a "koorpie," when they are from six to eight months' old, and have attained a height of at least twelve inches from the ground, and care should be taken not to allow them to remain too long before replanting, and to preserve as much of the soil of the nursery bed adhering to the roots as possible, and also, as a matter of course, not to injure the latter. An excellent little tool for transplanting the seedlings, and one which enables balls of their own earth to be kept attached to their roots without any difficulty, is Jaben's patent transplanter, an ingenious device of great simplicity and

handiness, and very inexpensive. If possible, cloudy weather should be chosen for the transplanting operation.

The holes at the stakes for the reception of the seedlings are, as a rule, first roughly made by the coolies by means of hoes, then deepened if necessary by the women transplanting the seedlings, by means of the before-mentioned iron-shod stakes, the plants being then so placed in these holes that the tap roots are in their natural positions, and not doubled back, and the holes afterwards filled with earth and well rammed in and trodden down.

A point to be carefully attended to is not to transplant any of the weakly seedlings. No seedling should be pruned at all near the time of transplanting, or after it has produced lateral branches.

Before filling in a space due to the death of any of the seedlings, the spot should be well dug out, and the ground exposed to the air and mixed with quicklime, the hole being well manured and covered with some of the earth.

Pruning.

As soon as the young tea plants begin to run up too much, and to assume the form of trees rather than of bushes or shrubs, which will be in about two years on an average, although certain individual bushes will do so at an earlier date, pruning will have to be resorted to. Much diversity of opinion exists, however, as to the proper time to commence this operation. Mr. Christison advocates the training of the bushes when young. From the third year the plants are all pruned in accordance with their form and condition, every year regularly. Pruning has for its objects the getting rid of the knotted and unproductive wood, the thinning out of the shrubs so as to admit light and air, whilst leaving the young and vigorous leaf-producing branches and shoots; the training of the shrubs to the proper width; to form suitable flushing surfaces; and, finally, to prevent them from attaining such a height as to render it difficult or impossible for the coolies to pluck the leaf, it being noted that most of the leaf is gathered from the tops of the bushes. The work of pruning is one which both consumes a great deal of labour and also requires very careful supervision.

Most Suitable Soil for the Growth of the Tea Plant.

As regards the nature of the soil requisite for the successful growth of the tea shrub, although the opinions of experts vary to a great extent as to the exact constituents best for the purpose, one thing, at any rate, ought apparently to be certain, and that is, that the soil should be a rich one, in order to enable the plants to withstand the severe trials to which they are subjected by the repeated stripping of their leaves, which, in poor soils, would, it is only natural to suppose, cause them to quickly pine away and die. This deduction is not, however, entirely borne out in practice, the soils of China and Assam found suitable for the growth of tea being only classes of poor yellow loams, as will be seen from the following analysis of the tea-growing soils of these countries:—

Analysis of Soils of China and Assam Tea. (*Piddington.*)

	Soil of China.	Soil of Assam. Surface.	Soil of Assam. 2½ ft. down.
Water	3·00	2·45	2·00
Vegetable matter	1·00	1·00	·80
Carbonate of iron	9·90	7·40	6·70
Alumina	9·10	3·50	5·45
Silex	76·00	85·40	84·10
Traces of phosphate and sulphate of calcium, and loss	1·00	·25	·95

It will be seen that the above soils contain no chalk, and the tea shrub likewise seems to be able to exist with the merest trace of lime[1] in the soil, salts of magnesium apparently taking their place. Sulphates also are only present in very small quantities. Phosphoric acid and salts are only present in a state of great insolubility. Suitable soils for tea growing are, however, invariably rich in nitrogen. Mr. Crole,[2] an authority upon these matters, remarks, in his interesting and instructive work, upon the great diversity of opinion that seemingly exists with reference to the

[1] See table, page 410, for amount of lime found to be contained in various tea soils by Kelway Bamber.

[2] "Tea," by David Crole (London, Crosby Lockwood and Son).

most suitable soil for the growth of the tea plant, amongst those whose experience should qualify them to rank as judges in the matter. In selecting a soil, says Mr. Crole, the following conditions should be borne in mind:—Climate, as regards rainfall and temperature, and also the drainage; the chemical nature of the soil; the physical nature of the soil, that is, its state of division. The same authority further states that bamboo land is peculiarly suitable for tea, but that it is expensive to clear. Bheel soils, when properly drained and opened, he considers to be admirably suited for the crop, and teela soils, on the contrary, to be most undesirable, whilst peaty soils are highly forcing. When freshly cleared the bush or jungle should be burned, the ashes hoed in to correct the sourness, and the land well drained to oxidize and remove the poisonous constituents. The best results, moreover, are, according to the same gentleman, obtained by cultivating this class of soil as little as possible, so as to prevent the loss of nitrogen and organic matter, which it is very rich in, but with which it is apt to part with great ease and rapidity.

As regards the views of other experts upon this point, it seems that Wallich and McClelland both hold the opinion that the tea plant has a decided disposition to adapt itself to any soil, as least so far as regards its powers of vegetation. Wild indigenous tea, they state, is generally found growing on a loose, dry, and dusty soil, sinking under the feet with a certain amount of elasticity owing to a dense ramification of fibres, both the soil and the subsoil being highly porous. A light, red, dry, dusty soil, at a level of a few feet above the surrounding land, and of a dark yellowish brown colour at the surface, getting brighter away from the latter till a deep pure orange-coloured sand is reached a few feet down, they likewise deem very favourable to the growth of the tea plant; the special feature in this, as also in the former soil, being a remarkable degree of porosity.

Fortune[1] says that, in order to be profitable, tea should have a good sound soil, such as a light loam well mixed with sand and vegetable matter, moderately moist, and yet not stagnant or sour.

[1] Robert Fortune, Bot Col Hort Soc Lon, author of "Three years' Wanderings in the Northern Provinces of China," "Two Visits to the Tea Countries of China, and the British Tea Plantations in the Himalaya," &c.

Referring to the China tea plant, Ball avers that it delights in very high situations, a compact and rich soil, a cold and humid temperature, and an eastern[1] aspect, the soil being of such a texture as to receive and part with its water freely, and it being on the just balance between these extremes that its suitableness depends, which latter must be regulated by its locality.

Gordon prefers a free soil, which is neither wet nor dry, but of such a nature as to retain moisture. Contrary to the opinion of the preceding authority, he holds that an easterly exposure is fatal to success.

Christison, referring to experience in Darjeeling, says that all aspects grow tea almost equally well, but though the southern and south-eastern are drier and more difficult to plant successfully, he considers that, on the whole, they are preferable when opened out. The northern aspects require less care and less skill, and are not so risky for vacancies, but have comparatively more in their favour at low, dry altitudes than high. Gentle slopes are undoubtedly preferable. Great difficulty is experienced in getting tea to thrive on the site of native homesteads.

Guillemin asserts that the plants seen by him on a plantation which he visited showed a remarkable luxuriance of growth, which he ascribed to the richness of the soil and the quantity of decomposed vegetable matter contained in it.

Von Siebold states that in Japan the most congenial soil to the growth of the tea plant is found to be one of a clayey, heavy nature, rich in iron, and containing fragments of wacké, basalt, basaltic hornblende, and fossils peculiar to the trap formation, which soil is sandy and chalky, and which on being washed exhibits but very little vegetable mould.

Bamber affirms that pale reddish-coloured rather sandy loams, containing a good proportion of organic matter, and with an open and free subsoil, are the best suited for the growth of the tea plant.

Whatever may be the difference of opinions amongst experts as to the exact constituents most desirable in the soil, it is clear that in the case of such a deep-rooted plant as the tea shrub the

[1] The most fertile tea gardens or plantations in China are along the slopes of the Bohea mountains, to which the requisite moisture is brought in summer by the south-east monsoons.

nature of the subsoil to a very considerable depth is of the utmost importance.

Manuring.

Crole declares that the manuring of the tea plant is a subject which has received but very little attention in India, it being the general opinion in Assam, indeed, that the soil, more particularly that of the upper districts, does not stand in any need of manure. Liquid manure is frequently placed round sickly or weakly seedlings after transplanting; and severely pruned and sickly plants are, in a number of gardens, manured with cow-dung either by itself or mixed with the ashes of sawdust. According to the above mentioned gentleman, however, this treatment, which would be very good in its way were it rationally made and applied, is rendered more or less abortive by reason of the manure having as a rule, before use, parted with the major portion of its valuable properties, especially its nitrogen, owing to a want of knowledge of the subject on the part of the planter, and to the operation being carried out in an irrational and half-hearted manner not calculated to produce the best results. He furthermore opines that should any steady diminution of turn-out set in, planters would then take up the subject of manure fast enough.

Other manures mentioned by the same gentleman as being obtainable in India are the following:—Margossa cake; fish manures; bats' guano; rape, mustard, poppy, niger, sesamum, linseed, and cotton seed cakes; bheel soil; bone manures; guanos; wood ashes; sulphate of potash; bone-black; saltpetre; sulphates of iron, calcium, and ammonium; and basic slag.

Lime is not required as a food for the tea plant, but may be employed to neutralize sourness in the soil in the form of gypsum; or to break up and render more open or porous soils of a heavy clayey nature in the form of quicklime.[1]

Christison is of the opinion that the manuring of the tea plant is for many reasons a difficult matter, and not one of any pressing necessity owing to the crop being neither heavy nor exhaustive, and to more nitrogen being returned in the rain in warm than in more temperate climates. The average crop of green leaves taken

[1] See table compiled by Kelway Bamber giving the value of various manures for the growth of the tea plant, page 411

from the soil does not exceed 12 cwts. per acre annually, or about ½ lb. per bush. Mr. Christison attaches most importance to green manuring by means of turning into and burying in the soil in autumn the greatest possible amount of fresh and decaying growth. He also strongly recommends top-dressing with leaf mould, or other rich mould, or even a thick dressing of poor soil on thin dry parts. Manuring, and especially top-dressing, he considers to be useless unless very liberally applied in layers of from three to five inches in depth.

CHAPTER II.

PLUCKING OR GATHERING THE LEAF.

Various Systems of Plucking or Gathering—Hand Plucking or Gathering—Mechanical Plucking or Gathering

THE primary operation in the process of manufacture is the plucking or picking of the leaf, the first of which takes place as soon as the first flush begins, that is to say, when the plants have sprouted to a sufficient extent to admit of the plucking being performed, which in India is in the latter half of the month of March.

Naturally tea is not made from the old hard leaves, but from the undeveloped bud and the youngest and most succulent leaves at the points of the growing shoots, the former yielding the finest tea.

VARIOUS SYSTEMS OF PLUCKING OR GATHERING.

When about five leaves have become developed on each shoot the season has commenced and they are fit to pluck, and the manner in which this first plucking is performed will have a very important afterbearing upon the yield of the bushes during the rest of the season. If, for example, the new shoots be picked off too close to the old wood of the year before, the bearing surfaces of the plants will be obviously greatly reduced, whilst, on the other hand, if not plucked at the proper time and distance, they will become too long and wild to produce the succeeding flushes with the proper rapidity.

The extremity of the shoot with the bud and either one, two, or three leaves, are nipped off in accordance with the quality of the tea desired, viz., fine, medium, or coarse. The most general system of plucking adopted in Indian and Ceylon plantations is

two and a bud, and what is known as the single banji or barren leaf is also plucked, the double banji is not touched, except it be by accident or by carelessness, which is frequently the case, as it greatly resembles one and a bud.

With respect to this, Crole is of opinion that both the single and double banji leaf should be severely eliminated from the bushes, not so much, he says, for the sake of manufacture (as these leaves may be thrown away if the admixture of them with the other leaf is found to weaken the liquor of the manufactured tea seriously, or may be manufactured separately as a coarse tea if it is found to pay the expense of its manufacture), but in order that as little sap as possible may be diverted from the shoots which bear "tip" (bud). The above gentleman states that he himself has carried out experiments regarding the above, which fully answered his expectations so far as they went, but which he thinks should be so conducted as to allow of a careful comparison of the results arrived at for a long period covering several seasons being made, before a decided judgment could be arrived at, and in any case the experiment could in no way adversely affect the flushing of the bush, except perhaps in the case of delicate jât tea.

The following description by Mr. Christison [1] of the operation of plucking or gathering as carried on in Darjeeling will be of interest:—"In early times three, sometimes four, if not occasionally even more leaves were gathered, but more recently quality has become more and more the aim annually; and now it is the common practice to take only two leaves and the bud, but in some instances plucking is so select as only to embrace one leaf. The bud yields the finest tea of all, *i.e.*, the 'golden tip' or 'silver tip,' the top leaf forming the next quality, 'orange pekoe,' or, when large, 'pekoe,' and the second or lower leaf generally yielding pekoe, but 'pekoe-souchong' when the leaf is large. Commonly the first shoots of the new growth of the season bearing four, five, or six leaves go to make up what is termed the 'first flush.' The two top leaves of this, or in some instances only one leaf with the bud are plucked—that is cut off with the incipient tender stalk between the finger and thumb—for tea; the remaining leaves and stalk

[1] "Tea Planting in Darjeeling," by Geo W. Christison Journal of the Society of Arts, June 12, 1896.

being far too developed for quality and necessary for the health of the bush, and the giving out of subsequent 'flushes' are left. After the first flush, less fresh growth requires to be left, and after three or four months of discriminate, sparing cropping, the bushes have become sufficiently made up and fortified for the season, all the fresh growth that will make tea of prime quality may be gathered without risk of injury to the plants. The pluckers have to go round the gardens at intervals of from five to eight days, extended from nine to eleven days towards the close of the season, according to elevation. It is the pluckers' duty to avoid gathering too coarse leaves or unripe shoots, to miss no good, suitable leaf, and prevent the heating in the baskets of all that has been gathered. In plucking, much discrimination as well as dexterity is necessary, and though perfection may not always be attainable with many hundreds, including often a proportion of untrained pluckers, employed, the operations over the scattered fields on those steep rugged hillsides require all the more unremitted attention and arduous supervision to obtain the most satisfactory results practicable. It is well when the leaf can be delivered at the factory twice during the day, but this is not always advantageous when the range of elevation is great. On plains gardens this is comparatively easy, light tramways being occasionally in use for the purpose. The cropping season generally lasts from the end of March till the middle of November. The crop varies from eight to fifteen cwts. of green leaf per acre annually, which yields barely one-fourth its weight, say from 200 lbs. to rarely so much in the present day as 400 lbs. of prepared tea per acre."

In both India and Ceylon the teas produced from the first flush are always inferior in quality, presumably because the constituents, which impart to the tea the strength and flavour peculiar to it, have not had time to become completely formed.

In China and Japan, on the contrary, strange to say, the first pluckings produce the best grades of teas, the quality deteriorating each time, at every succeeding plucking of the season.

In the northern parts of China the season commences in April and the first gatherings consist of delicate young leaf-buds which produce a tea of a very special quality, none of which, however, ever leaves the country. This plucking is very injurious to the plants, but the spring showers enable them to recover and put

forth a fresh growth of leaves, and three further pluckings are made, the last being in the end of September.

The plucking season in Japan is practically the same as in China.

In Java the plucking is said by Jacobson to be divided into three classes of leaves, each gathered by separate men. That is, the first leaf and the bud is taken off by the first party of pluckers, the second and third leaves by the second party of pluckers, and the fourth and fifth by the third party of pluckers, who likewise pick the sixth and seventh leaves if they are fit to make tea, being careful however to leave two buds upon each shoot.

In former times it was customary in India to pluck the bushes very coarsely, and consequently each plucker was able to bring in about double or even three times the amount of leaf which they are able to do at the present day with two and a bud plucking.

It is held by some authorities upon the subject that a better system of plucking, at least theoretically, than that of two or three leaves and a bud, is to pick two and a half or three and a half leaves and a bud. The advantages claimed for the latter system are, firstly, that it allows of a greater rapidity of flushing taking place; and, secondly, that it prevents the presence of any stalks in the tea, the absence of which both improves its appearance, and furthermore renders sorting previous to fermentation a far easier matter to perform.

With good jât bushes which have grown well, a preliminary plucking may commence when they have attained the age of two years, this preliminary plucking, however, consists of tipping only, and is all that they are first subjected to, the plucking properly so called not being started until between the third and fourth year. At the age of five years these bushes should be giving the fullest supply of leaf of which they are capable.

This refers, however, to tea plantations located on the plains; in hilly districts a garden cannot be expected to be self-supporting under six or seven years. Once arrived at maturity, if given judicious and fairly skilful treatment, the bushes should go on yielding full crops indefinitely, replanting being of course made where rendered necessary by the occurrence of vacancies.

With respect to Indian tea plants, it seems to be generally held

that hard plucking at the commencement of the season is injurious, and that the bushes should be lightly plucked at first so as to permit the formation of wood for future flushes. Chinese tea, on the other hand, seems to thrive better with hard plucking.

That the number of flushes which can be secured in a year are in direct proportion to the degree of cultivation maintained on the plantation has been abundantly proved by the fact that those secured on the Indian plantations have now increased greatly beyond the three or four flushes which were obtained in the years when the tea planting was first started there. Probably by the judicious use of manure, and by the still further improvements in cultivation which the use of steam power would render possible, the number of these flushes could be still further added to, as well as effecting an advance as regards their prolificness.

In Natal the picking or plucking season generally commences in September, and continues until about the end of the following May. Coolies are found to be preferable to Kaffirs for the work, the former being on an average able to pick or pluck forty-two pounds of green leaf per day each, whilst the day's work of the latter does not exceed nineteen pounds each on an average. The smallest leaves on the twig, when picked, make the finest tea.

Hand Plucking or Gathering.

Plucking by hand is effected by nipping or pinching off the shoot between the thumb nail and the fore or first finger, the thumb being turned downwards during the operation, and the separation of the part being completed by giving a slight jerk. The daily task required of a plucker in India is from twelve to sixteen pounds a day, and the maximum amount plucked by one hand working overtime will be about twenty-five pounds.

It will be seen from the foregoing that hand plucking is at best but a slow operation, and, moreover, that it is not a particularly cleanly one.

Mechanical Plucking or Gathering.

From time to time various inventors have attempted to devise instruments that would more satisfactorily perform the operation of plucking than can be done by hand, but hitherto, it must be

admitted, with only a very doubtful amount of success, indeed the operation would appear to be one of those which it is practically impossible to execute by mechanical means as well, and as judiciously, as it can be done by hand.

One mechanical plucker which has been used to a limited extent consists of a pair of shears having a rim of two or three inches in height running round the upper surfaces of the blades, to retain the leaves severed from the tea shrub at each cut of the blades. To enable this instrument to be used the bushes would have to be so pruned as to present as flat top surfaces as possible.

The drawback to this, and indeed to all mechanical pluckers, is that the work performed by them is of a very mixed description, containing not only bits of coarse leaf, but also thick stalks and stems, and entailing a large amount of after work in the way of sorting.

CHAPTER III.

TEA FACTORIES.

Choice of Site for the Tea Factory—Most Suitable Materials for Building the Tea Factory—Foundations for the Tea Factory—Internal Arrangements of the Tea Factory.

An important, if not, indeed, the most important, factor in the successful working of a tea plantation is the provision on the estate of a properly designed and well-built factory fitted with machinery and appliances of the most approved construction for the manufacture or dressing of the leaf, and handling of the tea; in fact the possession of a good jât, of a suitable soil at a proper elevation, and of an appropriate climate, of fundamental importance though they be, and though, combined with good cultivation, they may enable plentiful crops and good quality of leaf to be insured, will be stultified if the factory be wanting in any essential particulars, whilst, on the other hand, with a factory well-equipped in every particular, good tea can be turned out even with leaf from tea-bushes indifferent owing to inferiority of jât and soil.

Choice of Site for the Tea Factory.

An important point relating to the tea house or factory, as it is with regard to works on any other description of estate, is to erect it on the most convenient possible site; and as the leaves have to be conveyed from every portion of the plantation to this particular spot, the centre of the plantation, as being the nearest to all, should theoretically be the best location.

There are, however, many other considerations which must not be overlooked when choosing the site, and which unfortunately do not always admit of the central one, or even of an approximately central one, being decided upon; but, in such cases as where the

above location is not rendered impossible by reason of any of the objectionable features which will be found enumerated below, it should always be fixed upon, and all the paths, roads, tram or railway lines, and ropeways or cableways, be so laid out as to converge upon this central, or approximately central, point.

The objectionable features which may render it inadvisable to pitch upon the middle, or upon any point near the middle, of the plantation for the site of the factory are as follows:—

The ground being at too high a level as compared with the surrounding land, thus making the gradients up to the factory of excessive severity, and increasing the labour of transporting to it the leaves, as also the stores and materials, to an abnormal extent, and furthermore causing it to be a matter of impossibility, or one of great difficulty, to obtain the necessary supply of water for boiler-feeding purposes; the ground, on the contrary, being at too low a level as compared with the surrounding land, thereby rendering the building liable to be flooded, and giving rise to a great probability of the loss and inconvenience consequent thereon. And, lastly, but which is not of the least importance, increased facility for delivering the chests of manufactured tea from the factory to the nearest railway line, or to the wharf on the nearest river or canal, may render it advisable to build the factory at one end of a plantation, or even at a little distance from it, if thereby it can be located alongside a railway station, or so as to be easily connected with the railway line, by a short siding, or with the wharf on the waterway.

It may here be remarked that in all tropical countries water carriage is fraught with many difficulties. In one season, for instance, the heavy rains produce floods frequently spreading over large tracts of ground, and if not rendering unnavigable the rivers and canals, at any rate completely overwhelming the wharf or landing, whilst in the other or dry season, the rivers recede to their natural beds.

In India, this effect is aggravated by a combination with the heavy rains of the water produced by the melting of the snow on the mountains.

The result of this state of things is a necessity for the provision of two wharves or landing-stages, the one for use in the rainy season and the other in the dry season, and it is the first of these

that is of the most importance to the tea factory, as it is at that time of the year that the bulk of the manufactured or dressed tea is dispatched from the factory to the markets, the second being chiefly used for the landing of the stores and materials required on the plantation.

Most Suitable Materials for Building the Tea Factory.

The best site on the tea plantation for the factory having been duly selected, with proper regard to the points just mentioned, and to others of a special nature which will arise from various local considerations peculiar to the country, the next thing to be done is to decide upon the materials of which the building is to be erected.

The old tea houses were chiefly constructed with an entire lack of solidity, and with thatched roofs. The modern tea factory, however, is of necessity, on a plantation of any size, a much more imposing edifice, serving as it does for the housing of a considerable amount of machinery and apparatus.

The best materials at present obtainable are galvanized corrugated iron sheets and iron framework, or bricks with a galvanized corrugated iron roof. The building with brick walls is, of course, far and away the best, and should always if possible be adopted. The bricks will, however, as a general rule, have to be made and burnt on the plantation, thereby giving rise to considerable trouble, as the men selected for the work will of course require to be shown how to do it; and a special plant of machinery will also be required.

As regards the floors, that on the ground is best made of good concrete with a surface of Portland cement, but the upper floors may be of wood, except where exposed to any dangerous amount of heat. It is also advisable for further safety against fire that all the girders and joists, and any supporting columns that may be necessary, should be of iron, as also the roof.

Foundations for the Tea Factory.

It is almost needless to remark that every care should be taken to insure proper foundations for the structure, which it must be remembered is required to hold machinery, and will be subjected to the vibration caused by the working of this latter.

The foundations will, of course, have to be suited to the nature

of the ground upon which the building is to be erected, but it may not be amiss to give some general information thereon, and especially to impress upon those about to undertake such work the great importance of carrying the walls down to a sufficient depth to secure their having a solid foundation, of giving them a base of sufficient width to properly support them, and of putting in good concrete and brickwork below ground.

The best soil for foundations is gravel. Rock, if level, also makes a good foundation, if its nature should render it requisite; however, it must be levelled in steps, and all uneven parts should be filled up with large stones and strong cement. Sand likewise forms a good foundation in situations where it is dry, and not liable to be washed away; the presence of a leaky drain, or the excavation of a deep foundation, or any similar operation carried out in the vicinity is, however, almost certain to produce a subsidence. Clay is, as a general rule, about the worst and most treacherous ground for a foundation to rest upon, and it is usually damp. Made ground, even when of long standing, cannot be relied upon for the support of much weight. In such cases as those in which a stratum of soft ground is found to overlie hard ground, it would be found best to sink right down to the latter, when the depth of the soft ground is not over twenty feet, and to drive piles or sink masonry wells, when the depth does not exceed thirty feet. If the depth of the soft ground, however, be indeterminate, dependence will have to be made upon friction against the sides for support, and consequently the platform should be of additional thickness. Where a stratum of hard ground is found to be situated over soft ground, and the pressure per unit is not above that capable of being carried by the former, it would be usually found the best plan to build upon it, making the foundations as shallow as possible.

Where gravel or sand foundations are found to be situated over clay on an incline, the water should be intercepted by a drain on the upper side of the building.

When it is necessary to sink the foundations of a building to different depths, it is advisable whenever possible to use larger blocks for the deeper portions, so as to decrease the amount of mortar joints, and thus lessen the chance of unequal settlement taking place.

When piled foundations have to be made in deep, soft ground, sheet piles should be driven close together round the area before the main piles are driven, and when the upper stratum of the ground is very soft, it should be removed and filled in with either masonry or concrete, the latter being at least three feet in thickness. The upper ends of the piles should preferably be connected by timber cross-pieces notched on to the heads of the piles, and by longitudinal pieces running lengthwise of the foundations laid over them, the latter supporting 4-inch diagonal planking to carry the masonry. For 12-inch piles, these cross-pieces and the longitudinal pieces should be 12 inches by 9 inches.

When the piles are driven through soft ground on to hard ground beneath, their number must be proportional to the weight to be carried, and their cross-section greater in proportion to the depth, as each individual pile has to resist buckling in a similar manner to a column or stanchion. The maximum depth to which piles can be effectively driven is thirty feet.

In the case of brick walls, the base must be formed wider, so as to distribute the weight of the building over a more extended area, and conduce to an equal settlement. The trenches for the beds of concrete usually run from 2 feet to 7 feet in depth, and should be always made 12 inches wider than the base of the footings.

As regards the safe load which different foundations are capable of bearing, rock may be safely loaded with from a minimum of 1½ up to a maximum of 9½ tons per square foot, according to its degree of hardness and strength; and clean dry gravel, clean sharp sand supported laterally, firm earth, and hard clay, with from 1 to 1½ ton per square foot. In no case should the intensity of pressure upon a rock foundation be more than one-eighth its crushing pressure.

Internal Arrangement of the Tea Factory.

The various separate operations to which the leaf is subjected, and which together form the complete process of tea manufacture, consist of the following:—Withering or limping; rolling or curling; fermenting; drying or firing; separating, sorting, and cutting or equalising; and final firing. The finished tea is then packed for export. The entire process of manufacture generally occupies a period of from twenty-two to twenty-six hours.

Davidson's process for the manufacture of black tea from green leaf consists briefly in first combining the withering and fermenting processes by exposing the unrolled leaf to a constantly circulating current of moist air at about 135 to 140 degrees Fahr., whilst it is being lifted and dropped by shelves in a revolving drum for the purpose of breaking the cells without causing the juices to exude, the air being partially renewed at intervals for the purpose of supplying sufficient oxygen to the leaf. The leaf, which will by this time have acquired a brownish tint, is next rolled to complete the mixture of the juices, and is then dried. Or, after rolling, the leaf may be exposed to warm air for the purpose of evaporating about 10 to 20 per cent. of the moisture contained in it, after which it is again rolled, and, if desired, it may then be fermented in the ordinary way before drying.

With respect to the internal accommodation required in the main building of a tea factory, having regard to the above-mentioned operations, this must comprise a room for the artificial wilting, withering, or limping, of the leaf; a machinery room; a fermenting floor; a sorting room; a carpenter's shop; a packing room; and an office, which latter may be also used as a tasting or sampling room.

The houses for the natural wilting, withering, or limping of the leaf, are best arranged under separate roofs, and they form a very important feature of the tea factory, any deficiency of accommodation in this respect being likely to cause considerable loss and inconvenience when a big day's leaf is brought in, as will be the case during each day for which the rush lasts.

If, by way of example, a tea plantation of 1,000 acres, planted with good jât bushes on good soil and kept in a fair state of cultivation, be taken, every time that there is a good flush, an amount varying from 200 maunds, or 16,000 lbs., to 275 maunds, or 22,000 lbs.,[1] of leaf will be brought in each day whilst the rush continues, and as the withering or limping rooms should be of such capacity as to allow of the largest amount of leaf that is likely to be brought in being spread in sufficiently

[1] The maund is here taken as 80 lbs., but it varies very considerably in different parts of India, being 82·2840 lbs. in Northern India, 28 lbs. in Bombay, 24·686 lbs. in Madras, and 22 lbs. in Bengal. See tables, page 415.

thin layers to insure a proper action, the withering room or house should have 198,000 square feet of surface on which to wither the leaf; and as in very wet weather it would not be possible to wither the day's leaf and get it fit for rolling before the next day's leaf comes in, by means of natural wither, a sufficient accommodation for artificial withering must furthermore be provided to meet such an emergency.

In the natural withering, wilting, or limping houses, which are open at the sides, are arranged withering floors, or chungs, or withering racks, the former of which having only to support comparatively light weights, need not be of very strong construction, and must in any case be formed open, as it is absolutely necessary that the air should be able to pass through them to the layer of leaf.

The mode of construction hitherto usually adopted in Assam for these withering floors or chungs is to first place across the beams whole bamboos five or six inches, or even somewhat wider, apart. Then split bamboos are laid across these at intervals of about an inch apart and tied to the whole bamboos below them at every foot or foot and a-half apart. On the top of this floor or platform is placed the withering cloth, which being of a very coarse texture allows the air to pass through freely to the underside of the layer of leaves upon the cloth.

These primitive forms of withering floors, or chungs, are now, however, giving place to more modern arrangements for withering or limping, one of which consists in fitting up the withering rooms with racks (which may consist of stretched wires) adapted to hold trays made of wire meshing, in tiers, at distances of about six inches apart, which trays are practically similar to those used in the artificial system of withering for holding the leaf in the hot-air chamber, and upon which trays the leaf is spread in thin layers.

In another arrangement, wire netting of about half-inch mesh is stretched on tightly strained fencing wire, placed at a slant, so as to form surfaces upon which to spread the leaves, these floors or racks of wire netting being also placed at intervals of about six inches, the one above the other.

In the case of the old-fashioned withering floors or chungs above described, the first floor was constructed at either one

or three feet from the ground, and the succeeding ones at intervals of three feet apart.

The tea leaves are spread on the withering floors, or chungs, by children who acquire great dexterity at the work, the motion of the hand used being practically similar to that adopted when sowing seeds broadcast.

The leaves, when sufficiently withered, are, where the old-fashioned floors are employed, swept up by means of short brooms formed out of split bamboos, and in the case of the floors being constructed of wire-netting by first sweeping, and afterwards gently knocking the latter from below so as to cause any leaves that could not be removed with the brushes to fall down the slope to the ground. When trays are employed the removal of the leaves is a far easier task, all that is required being to remove the trays one by one from the rack and shake off the leaves on to the floor. The withered leaves are then swept into baskets and carried by hand, or on small trollies or waggons running on tram lines to the rolling machines.

The wire-meshed trays and the wire netting admit of considerably more withering surface being got into the same cubical space than was possible with the old-fashioned withering floors, and also, by reason of the freer access of air to the leaf, the latter can be withered or limped more rapidly on the trays or wire netting.

In an arrangement devised by R. Thomson the rack, tray, or shelf upon which the tea leaf is spread for the purpose of being withered or limped by atmospheric action consists of bands of wire stretched between standard frames, the inner edges being higher than the outer edges. These bands are clamped at their ends between plates, which latter are secured to one of the end standards, whilst at the other end standard the plates are caught by hooked rods tightened up by screws.

For transverse stretching a tube is employed, in a slot at one end of which the edged wire is carried, whilst at the other end a hooked rod with tightening-up screws is provided.

An arrangement for withering tea, designed by D. Rowell, consists of a drying room filled with trays which are formed of openwork material, and are supported at their corners by hooks engaging with chains or other suitable supports.

This arrangement admits of the trays being fixed in a horizontal position during the drying, limping, or withering operation, or allowed to hang vertically to discharge the withered or limped tea on to the ground.

When tramways are employed inside the withering houses they should be so arranged that the wire-meshed leaf carriers arriving on the trains from the plantations can be lifted on to the trolleys by means of a suitable crane, and run to any desired parts of the withering houses.

A much more efficient method of conveying the leaf from the weighing shed to the different parts of the withering houses, however, is a pneumatic conveyor such as that which will be found described and illustrated on pages 310 to 312.

The machinery room, that is to say, the room intended for the reception of the chief portion of the machinery, should be on the ground floor of the main building, the room required for artificial withering being situated on the floor above. This latter room having in the present case a floor area of 14,000 square feet, giving a spreading area of 40,000 to 70,000 square feet; it will be found described at length in a chapter devoted to the subject.

In a tea factory, suitable for a plantation, of the size already mentioned (1,000 acres) the ground floor space required for the machinery would be about 5,400 square feet. Slightly at one side of the centre, and lengthwise of the room or factory, a tram-line should be laid, and centrally or thereabouts and lengthways therein a line of shafting from which power can be communicated to the various machines at either side of it by means of belt gearing.

This line of shafting may be arranged either overhead or underground, the latter being found to be the most convenient arrangement in tea factories, as it has in this country for saw-mills, &c., and for the same reasons. When the shafting is located below ground a pit will have to be formed which should be about five feet in depth by about four feet in width. The bottom of this pit should have a flooring of about six inches of good concrete cemented on the top with Portland cement, and the side walls should be either of good concrete, likewise cemented on its inner face, or of brickwork. The bottom should also be arranged to slope slightly to one

end, at which a well should be formed some two feet deeper than the pit to receive any water that may gain access to the latter, from which well it can be pumped out whenever it may be found necessary to do so by one of the steam-pumps in the boiler-house.

At the one or the other side of this line of shafting, as may be found most convenient, should be placed the tea-leaf rolling machines, about seven of which will be required; the main motor, or engine, which should be of about 20 h.-p. nominal, assuming, of course, that steam is the power which is employed for driving; the drying and firing machines, five or six of which will be necessary; the machine tools required for such repair work as will have to be executed on the spot; the wood-working machinery, &c.

It may be here remarked that it is a great mistake to cramp up machinery as is so frequently done with the idea of economising space, at the expense of short belt centres, and the consequent serious loss by the slipping of belts, or by reason of the increased friction due to working with abnormally tight belts to prevent such slip, and by the difficulty of tending the machines when so crowded together.

Another matter, frequently causing both great inconvenience and loss, is the fact of the machinery provided, in almost every instance, being barely capable of dealing with the average amount of leaf which is brought daily from the plantations, and, consequently, when an unusual amount comes in day after day during a rush, the machinery will not be capable of dealing with it, and the leaf will have to be left lying about, greatly to its detriment, and with the undesirable result that an inferior quality of tea will be turned out, for it is simply absurd to expect, with the machinery working day and night for perhaps a stretch of three weeks at a time, that the best, or even good, results can be insured. It is, therefore, obviously necessary to have a plant of machinery capable of treating, without being unduly overtaxed, the largest day's supply of leaf that it is likely to be called upon to deal with.

The fermenting floor should also be situated on the ground floor, but if it is desired to save ground space a couple or more floors might be arranged in tiers, the one above the other, at

distances of about four or five feet apart, the latter plan, however, being obviously less convenient than the provision of ample fermenting surface on the ground floor. Whichever plan be adopted a total floor space of from 10,000 to 12,000 square feet will be required in the case of such a factory as that at present under consideration.

The floors are best made of Portland cement set slowly, and with a perfectly smooth surface, and they should be also arranged to slope towards a drain to carry off the water used for washing them down, and likewise that employed for keeping the cloths, covering the layers of fermenting leaf, moist.

A line of tramway will have to be laid round the fermenting floor, and the requisite drain could advantageously be formed in the permanent way of this line. This water might be collected in a suitable tank, and the theine, &c., be extracted from it.

If the fermenting surface be arranged in floors placed the one above the other, as has been already mentioned, the plan will create an extensive saving of ground floor space, at the cost, however, of its being considerably less convenient. The chief objection to the arrangement is that, in order to work it to advantage, tram lines would have to be laid down on each floor, and a lift or hoist be provided to raise the receptacles of rolled leaf, both of which would add very considerably to the first cost of the installation and also to the after expense of working.

These lifts and extra tram lines might certainly be dispensed with by stopping the fermenting floors short at the tram lines, where the leaf could be handed up in baskets from the trolley below, but the labour of spreading the leaf on the upper stages would, of course, be thus greatly increased.

It is generally considered desirable to be able to exclude the light from the fermenting floor whilst that operation is in progress, and also to be able to maintain as cool and as even a temperature as possible. The latter can be effected by a suitable instalment of refrigerating machinery.

Taking next in order, the sorting floors; these are at present almost universally arranged on the ground floor, and but very seldom on an upper floor of the factory.

The principal objection to the location of the sorting room on the first floor is the labour of transporting or raising the leaf up

to it, which would necessitate the provision of a crane, or of a hoist, or lift, to raise the receptacles containing the dried tea to the upper floor, and to lower them down again. An advantage, however, derivable from arranging the sorting room on the upper story, and one, moreover, of some importance, is that it enables the whole width of the ground floor to be devoted to the fermenting floor.

At one end of the sorting room should be placed the tea breaking and sorting machinery, and for hand-sorting the floor should be covered with sheets of tin plate, and divided off into a number of separate floors by means of partitions, which may be constructed of wood, and should be about a foot or eighteen inches in height, into spaces of about twenty feet square. The entire floor area required for the sorting room in a factory of the size under consideration will be about 4,000 square feet. In Natal, it is usual to place the finished tea in air-tight bins, and leave it to mature for two or three months.

The next part of the factory to be noticed is the carpenter's shop, in which the shooks or bundles of staves and pieces for the corners are formed into chests and boxes, and the necessary covers or lids. As this work is always done on Indian plantations by native carpenters, it will be necessary to fit up the shop with a view to suit their requirements, which are very simple. It is preferred by many to locate the carpenter's shop outside the main building in an annex or shed erected alongside the packing room, but if it be placed within the main building, which, in the author's opinion, is the most convenient arrangement, the best place for it is above the packing room, a situation which admits of the boxes and lids being conveniently lowered into the latter room, where they are required for use. The floor area should be about 5,000 square feet.

As steel chests and boxes are now becoming largely used, both on account of their extra capacity for a like outside measurement, as compared with wooden chests, and the consequent saving in the number of chests or boxes required for the transport of a given quantity of tea, and of the freight thereon, and also by reason of the tea being said to reach its destination in better condition, the arrangement of this part of the factory will in many cases be modified by their use, the carpenter's shop becoming in fact a room or shop in which the parts of these chests and boxes, which

are forwarded to the factory separate and packed flat for convenienc of transport, can be put together.

The last room or department, or that wherein the final operatio of stowing the finished tea in the chests or boxes for despatchin to their destination is performed, is the packing room; and thi latter room, as well as the office and tasting or sampling room which is most conveniently situated contiguous to it, should be o the ground floor of the factory, and, as above mentioned, preferabl underneath the carpenter's shop, or the room for putting togethe the steel chests and boxes, in cases where the latter are employed

In the packing room the wooden chests received from th carpenter's shop are lined with lead, and suitable fire-places wil have to be provided for heating the soldering bits or irons employed for soldering together the sheets of lead that form these linings, that is, of course, when wooden chests are employed. The chests, whether of wood or steel, are here filled with a certain specific quantity of tea, usually varying according to the kind of tea, and suitable weighing apparatus is consequently provided in this room, and here should also be placed the tea packing machines.

The chests having been filled with the determined amount of tea, are, if of wood with lead linings, soldered up, and the lids and strengthening bands or hoops nailed on to them; or, if of steel, the lid or cover is fitted in place and made secure; after which they are stencilled with the garden mark, the description of tea, and the number of each particular chest, and are then ready for loading.

The packing room should have a floor space of about 3,250 square feet, and it is advisable to have a lean-to roof or shed outside, which will form an additional space under which the loading up can be effected.

The office needs no description, and its size will of course vary according to circumstances, but, if possible, it should at least have a floor space of 1,200 square feet. All the account and other books connected with the factory and plantation are naturally kept there, and it is also usually used as a tea tasting or sampling room.

The boiler house is best situated at a certain distance from the principal building, and of course convenient to the main

engine in the machinery room, and two boilers, each of sufficient power to supply the engine, should be provided. By this latter precaution all chance of a stoppage occurring at an awkward time through the giving out of a boiler can be avoided, as they can be employed turn about, thus affording ample time and opportunity for cleaning them out, and for effecting any necessary repairs.

In connection with the boiler house a suitable chimney stack will have to be provided.

Next to the boiler house, and if desired under the same roof, may conveniently be located the smith's shop, which requires no particular remark, except that it is advisable to have here also a small foundry where new castings can be made.

In the immediate vicinity of the boiler house should be located a pond or reservoir, or other source of water supply for the boilers.

The store should ordinarily be a separate building, placed at some little distance from the other buildings of the factory, as it usually not only contains the iron, wire, implements, and other incombustible materials, but likewise paints, oils, and other more or less combustible ones. When, however, a separate detached store is provided for the oil and other combustible materials, the store-room for the incombustible tools and materials may be advantageously situated on the first floor of the factory if the space at disposal admits of it.

The repair shop has been already mentioned as being situated in the machine room in the main building, and it should be preferably partitioned off from this latter. It should contain a screw-cutting and surfacing gap lathe, a smaller screw-cutting lathe arranged to work by foot or steam power, a shaping machine, a milling machine, large and a small drilling machines, one or more emery wheels, a grindstone, and a proper assortment of stocks and dies, ratchet braces and drills, boiler tube expanders, and all the other requisite hand tools and appliances that may be required for putting down new machinery and for repair work.

A plan of a shop suitable for the purpose will be given later on in the chapter devoted to miscellaneous machinery and appliances, and also a short description of the various tools.

The wood-working machinery also mentioned as being located in the machine room, should in any case comprise a circular saw-bench, preferably with a rising and falling spindle; but where

the staves or planks for the tea chests are made on the premises, additional circular saw-benches and one or more band or ribbon saws, must be provided, and a small surfacing and planing machine would also be desirable, or a general joiner might be substituted for one of the plain circular saw-benches; this, however, will be more fully dealt with later on.

Thus far each separate part of the factory has been briefly described.

The folding plate shows a complete factory, suitable for a tea plantation of 1,000 acres. Fig. 1 is a sectional plan of the entire factory, Fig. 2 is a side elevation of the main building or tea house, Fig. 3 is an end elevation of same, and Figs. 4 and 5 are respectively a longitudinal and a transverse section thereof.

On the sectional plan, which shows the ground floor, A indicates the main or principal building of the factory, or what should more properly be called the tea house. B, B, are the houses for the natural withering or limping of the leaf. C is the machinery room of the main building or tea house, in which are arranged the main driving engine D, which imparts motion to the main line of shafting, the latter being arranged in a pit underground, as shown in dotted lines, the tea rolling machines E, the tea leaf chilling and oxidising machines F, and the tea drying and firing machines F^1; G is a circular saw-bench, H is a surface planer, and I are band saws. J is the repair shop which contains lathes K for turning iron, a shaping machine L, a milling machine M, a power drilling machine N, an emery wheel O, a grindstone O^1, and a fitter's bench O^2, fitted with vices O^3, and a hand power drilling machine O^4. P is the fermenting floor. Q is the sorting room, in which are placed the roll breaker, cooler and sorter R, the tea cutters and equalizers S, and the sorting machines T. U is the packing room, having packing machines U^1. U^2 is the loading shed. V is the office. W is the boiler house. X is the forge and foundry. Y is the oil store house. Z is the railway line, and Z^1 is the locomotive shed, the last four being separate buildings.

The artificial withering room, or loft B^1, store room A^1, and carpenter's shop A^2, are shown in the longitudinal section, Fig. 4, and transverse section, Fig. 5, of the tea house.

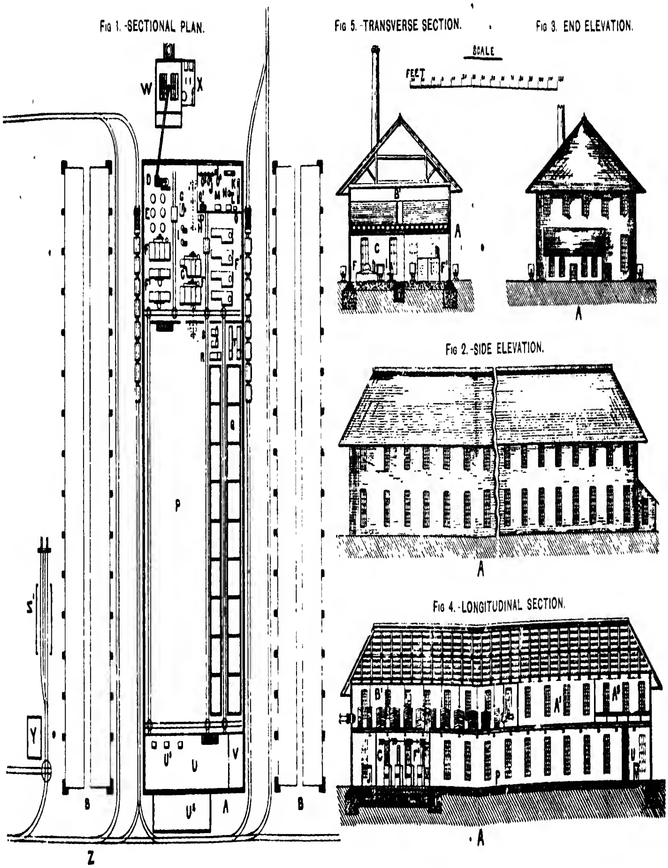


ILLUSTRATION OF A COMPLETE FACTORY FOR A TEA PLANTATION OF ONE THOUSAND ACRES.

FIG. 1 —Sectional Plan of the Factory, showing the main building or Tea House, Withering Houses, etc FIGS. 2 and 3 — Side and End Elevations of the main building or Tea House

FIGS. 4 and 5.—Longitudinal and Transverse Sections through the main building or Tea House

CHAPTER IV.

THE DRESSING, MANUFACTURE OR PREPARATION OF TEA BY MECHANICAL MEANS.

Limping, Wilting, or Withering the Leaf—Rolling the Leaf—Oxidizing the Leaf—Fermenting the Leaf—Second Rolling of the Leaf—Drying or Firing the Leaf—Sorting or Classification of the Tea—Re-firing or Final Firing of the Tea—Packing the Tea.

LIMPING, WILTING, OR WITHERING THE LEAF.

PRIMARILY the first operation in the process of dressing or manufacturing the leaf into black tea, which is that of limping, wilting, or withering the leaf, was entirely effected by natural means, that is to say, the leaf, spread in thin layers upon open floors, was merely exposed to the drying action of natural currents of air.

This plan amply suffices in favourable weather, and is still used, the mechanical or artificial method being only employed, as already mentioned, as an auxiliary, and being brought into operation in wet and cold weather. As hitherto effected, the process of natural withering consists in partially drying the leaf, the method usually employed of doing which is to expose it in thinly spread layers to the drying action of the sun's rays or to the action of the atmosphere until about 20 to 50 per cent. more or less of the moisture naturally contained in the leaf has become evaporated, whereupon the leaf will be then found to have attained the required limp and flaccid condition which is ordinarily known as withered.

The artificial process which is used in order to produce the evaporation necessary to bring about this withered condition more rapidly than would be possible by natural means is ordinarily

effected by spreading the leaf thinly on trays or racks in airy sheds or rooms, and by means of powerful ventilating fans causing large volumes of dry and slightly heated air to pass through and between the layers of leaf, the current of relatively dry air thus passing amongst the leaf drying it sufficiently to produce the above described withered condition; and it is universally accepted as a fixed rule in the manufacture of black tea that an evaporation of about 20 to 50 per cent. of moisture from the fresh leaf is essential to the production of the requisite withered condition, withering being thus in reality a partial drying of the leaf.

The mechanical or artificial means adopted for limping or withering the leaf consist, briefly, of various arrangements of fans, by means of which air which has been specially heated in suitable furnaces or air heaters in the one case, and the waste warm air from the machine-room, in the other case, is caused to pass over and through thin layers of the leaf spread upon trays supported in suitable racks. The machinery and apparatus used for artificial withering will, however, be more fully dealt with in a subsequent chapter, and consequently need not be further enlarged upon here.

The objects or purposes of subjecting the freshly-plucked leaf to the operation of withering, and the natural or physical action which takes place during the process are as follows:—

As regards the first, the reasons or objects of subjecting the leaf to the withering or limping process are manifold, and too numerous to be all mentioned here. The chief of them, however, is to begin to fix the aromatic principles, to effect the evaporation of the surplus water, and to facilitate the process of fermentation after rolling, the withering or limping process being the initial stage of that of fermentation.

The action of withering may be divided into two phases, viz., the physical and the chemical. Taking the physical action first: The freshly-plucked leaf is brought to the factory with all its cells charged with juices, which juices contain a very considerable proportion of water, and in a healthy flush during wet weather the cells will be found more gorged and their coats thinner than will be the case during dry weather, and in a banji (barren) flush they will be coarser and not so porous. To attempt to roll a freshly-plucked leaf before subjecting it to the withering or limping process would be to crush it into fragments, because

the cells are so charged with juice that the slightest rough usage will cause them to burst, and the resinous matters, besides, are in a fragile condition and render the leaf itself brittle. By the application of a certain amount of warmth, an evaporation of the moisture of this juice is effected from the cells through their pores, and at the same time the matters or constituents of a resinous nature are either destroyed or softened and rendered pliable.

In the mechanical or artificial process of withering, wherein there is a continuous application of warm air, and means are provided for the removal of the moisture-laden air from the immediate vicinity of the leaf, the process of evaporation will be rapid and continuous, and after a certain time—which to insure the best results should not be prolonged to excess, as Nature should only be assisted by the removal of all obstacles from her path, and on no account must be forced or coerced—every cell will have given up a portion of the moisture of its juice, the resinous constituents having at the same time been destroyed or softened, and the leaf will have assumed what may be called a satin softness and be in a condition to withstand a treatment by which it would have previously been burst, and will be in a fit state to safely undergo the process of rolling, which is next proceeded with.

It will be noted that the process of withering is only intended to produce the evaporation of a sufficient portion of the watery or fluid constituents of the juice to enable the leaf to undergo the somewhat rough treatment to which it will be subjected in the rolling machines, without causing any grave injury to the tissue and form of the leaf, and without removing any of the requisite principles which it is for the present advisable to retain.

In other words, the juice has become concentrated by the evaporation of the superabundant moisture from it, the needful principles being retained to be subsequently operated upon, and only that portion which tended to over-dilute them being removed by evaporation.

The principal chemical change taking place during the operation of withering is the production of an incipient oxidation of a certain portion of the elements of the juice.

If the process of withering be allowed to proceed too far, the cells will not become fractured during the subsequent rolling

process; a portion of the requisite elements of the juice will be no longer in solution, and, by reason of there being an insufficiency of juice to coat the entire surface of the leaf when rolled, an uneven colour will be developed during the process of fermentation.

ROLLING THE LEAF.

The leaves having been limped or withered in as even a manner as possible, should be next transferred to the rolling machines, which will be found described and illustrated in Chapter VI., in order to undergo the operation of rolling.

The reasons for subjecting the leaf to this operation are twofold: first, to burst the cells and liberate the concentrated or dehydrated juice for the purpose before mentioned, and, second, to impart a certain amount of twist or roll to the leaf, which is supposed to improve its appearance.

Whilst this process is being carried out, the colour of the leaf becomes altered from a fresh green tint to a yellowish one, and the best grades of leaf do not require to be as heavily rolled as those of a poorer quality, or as leaf which has been too much withered. The time occupied by the treatment of the leaf in the rolling machine consequently varies in different districts, and runs from ten minutes to three-quarters of an hour.

The heated air present in the casing of the rolling machine, especially in closed machines of the pressure type, likewise causes certain chemical changes to take place during this operation. According to Kelway Bamber,[1] some of the organic acids, principally the tannin, undergo a partial oxidization, a portion of the tannin combining with the oxygen to form phlobaphene, glucose, and gallic acid, and assuming a dark insoluble form during the process, and another part of the tannin forming an insoluble leathery substance by combining with a portion of the albuminous matter, the two latter reactions being only incipient at this step, and becoming more completely developed during the process of fermentation, which, when not passed through an oxidizing machine, is the next operation to which the leaf is subjected.

[1] "Chemistry and Agriculture of Tea, including the Growth and Manufacture," by M. Kelway Bamber, M.R.A.C., M.R.A.S. Eng., F.C.S., late chemist to the Indian Tea Association.

Oxidizing the Leaf.

After the rolling of the leaf has been completed, it would be found advantageous to expose it to the action of an oxidizing machine, such as that described in detail on pages 124 to 128. The objects of this operation are to chill and oxidize the rolled leaf after it has left the rolling machine, and likewise to evaporate a certain portion of the moisture that is contained in it.

Briefly, the apparatus consists of openwork trays to contain the leaf, each of which trays can be separately placed in communication with an exhaust fan by which the air of the room will be drawn down through the leaf, thus causing an evaporation of moisture from it which chills or reduces the temperature, from that at which it was placed on the trays, down to about 60° or 70° Fahr., thereby enabling fermentation to be carried out at a low temperature.

When the rolled leaf is passed straight on to the oxidizer trays, the effect of the air passing through it is to render it more sticky and gummy. This latter feature is claimed to allow of the leaf, during any subsequent fermentation to which it may be subjected, acquiring a highly agreeable aroma, and also to cause the liquor of the finished tea to be brisker than would be the case if the fermentation were to be carried out without first passing the leaf in the above manner over the oxidizer to chill and evaporate a portion of the moisture out of the juices.

Fermenting the Leaf.

The only machines used in connection with the process of fermentation are rolled tea-leaf ball breaking machines, which will be found described and illustrated on pages 118 to 124, and which are designed for the purpose of breaking up or disentangling the interwoven lumps or balls of leaf created during the rolling process. If the leaf be passed through these machines immediately after its discharge from the rolling machines, it will be also cooled down at once to its normal temperature.

Previously to the introduction of machinery, the lumps or balls formed in the rolling machines had to be picked to pieces by hand.

The process of fermentation is carried out by spreading the

leaf evenly upon a dark, cool, clean floor, specially laid down for the operation, in layers of one or two inches in thickness, and covering it over with strips of thin cloth—a kind of common muslin being usually employed for the purpose—thoroughly saturated with pure cold water.

The amount of fermentation to which the leaf should be subjected is found to vary upon almost every plantation, being apparently governed by the nature of the soil in which the tea plants are grown, and consequently its proper duration varies from as high as eight hours down to as low as two hours, the exact time required being in each case only to be found by practical experience.

The older, and now practically abandoned, method of fermenting the leaf by spreading it in thick layers upon trays, is said to have given far inferior results.

In the course of the extensive researches made by Kelway Bamber, he has been unable to discover the presence of any micro-organisms during the fermenting process, and he is therefore of the opinion that no fermentation at all takes place, and consequently that it is a misnomer to so style it. The truth most probably is that what is known as the fermenting process in reality is merely an oxidation one.

The changes said to take place during this process comprise the following:—

The further formation of essential or volatile oils; more of the tannin becoming converted, and thus causing a further reduction in the astringent nature of the tea; and the formation of gallic acid and glucose to a limited extent out of some of the tannin.

It is said to be desirable as soon as the leaf has been properly fermented, to again subject it to the action of a leaf-chilling and oxidizing machine. The advantages of this treatment are said to be that it instantaneously fixes the colour of the leaf, and that the chilling which the latter receives temporarily checks any further fermentation prior to its being passed into the drying or firing machines.

Second Rolling of the Leaf.

After fermentation, the leaf is usually again transferred to the rolling machines to restore the curl, which has been more or less

destroyed during the operation of fermentation, before being passed on to the drying machines.

This second rolling should not be so heavy as to break the leaf, and, moreover, should only be of but brief duration, from ten to twenty minutes being sufficient.

Some planters dispense with this second rolling of the leaf, and after fermentation transfer the leaf directly to the drying machines. Others, again, roll the leaf three times, viz.: The first time, after the withering or limping operation has been effected; the second time, when the process of fermentation has been about half carried out; and the third and last time, after the completion of the process of fermentation.

Drying or Firing of the Leaf.

The next operation consists in drying or firing the fermented leaf, which process was formerly usually effected in three, and sometimes in two, stages, and is now frequently performed in one stage by passing it through some suitable form of drying or firing machine, several patterns of which will be found described and illustrated on pages 131 to 232. When the operation is carried out in several stages, the first stage consists in passing the leaf somewhat quickly through one of the automatic drying machines, in which the fermentation will be immediately checked, the leaf being also somewhat more than half dried, and assuming a more or less black shade of colour. The partially-dried leaf is then passed through another drying machine, also of an automatic pattern, out of which it is delivered within about 10 per cent. of being completely fired. Finally, the tea is put through a firing machine of a type wherein the leaf is under control during the operation, and it leaves this machine completely fired tea.

When the operation is carried out in two stages only, the leaf is first about three-quarters fired in an automatic type of machine, and is finished off at the next stage in a machine of a type in which it is under control during the operation.

During the first stage the leaf should not be subjected to a greater heat than 300° Fahr., and during the two latter stages the heat should not be much in excess of 200° Fahr., and the

heated air should be in as dry a condition as practicable when passed into the machines.

The drying or firing operation may be carried out in stages in some forms of modern automatic drying machines. Or it may, if desired, be effected without any danger of burning the tea, if reasonable care be exercised, in one stage in the same machines, being fed in at one end in the damp or moist condition, in which it is left after the fermenting and second rolling operations, and discharged fully dried at the other end.

In carrying out this part of the process of the manufacture of tea, it should be borne in mind that the chief object of the drying or firing operation is to deprive the leaf of its moisture as completely as possible, without removing the essential oil and other valuable elements.

Sorting or Classification of the Tea.

The rough tea is next subjected to the operation of sorting or classification, the machines employed for this purpose consisting of the tea sifters or sorters and tea cutters or breakers, which will be found described and illustrated on pages 233 to 249.

The tea is first picked over by hand or passed through a mechanical sorter, and all the foreign matter removed, and any red leaf that may be mixed with it is likewise carefully eliminated. It is then put into a hopper and delivered into one of the tea sifters or sorters, which consists of either a hexagonal or other many-sided, or of a cylindrical, sieve or screen of considerable length, and which is usually of a smaller diameter at the end into which the tea is fed than at the other extremity, and which should be rotated at a speed of about forty or fifty revolutions per minute. This sieve or screen is formed in two or three sections of unequal dimensions, each of which is composed, moreover, of a mesh of a different size, the smallest being at the feed end, so that the tea fed in at that end will be divided or classified into two or three qualities or sizes, according to the number of sections in the sieve, whilst the larger leaf, not able to find its way through the meshes in any of the sections, will be delivered out at the end of the sieve or screen.

The first teas passing through the various meshes of the sieve

are known as unbroken teas, whilst that delivered or passed out at the end of the sieve is removed and put through some form of tea cutter or tea breaker, by which it will be reduced to a finer state, and is then again delivered to a sieve or screen of a similar construction to the first, by which it will be automatically sorted out or classified according to size, these latter products being known as broken teas.

In addition to the above, it is usual to again sort each of these different kinds of teas separately, so as to remove any foreign matter that may have escaped the previous operation.

Re-firing or Final Firing of the Tea.

The different teas are then subjected separately to the operation of refiring or final firing, which completes the manufacturing, or at least the dressing process of manufacture, and finally finishes the tea.

This refiring or final firing, being simply intended to remove any slight amount of moisture which the tea may have taken up from the atmosphere in the interval that has elapsed since it was passed through the drying or firing machines, need not be of long duration, but the temperature to which it is exposed should be rather high.

Packing the Tea.

The finished tea is now conveyed to the packing room, where the final operation of placing it in the lead-lined chests or boxes, or in steel chests, is performed either by hand in primitive establishments, or through the medium of any one of the several types of tea-packing machines, which will be found described and illustrated on pages 250 to 266, in factories fitted with modern appliances.

This completes the operation, so far as the tea factory is concerned, and the product is then ready for forwarding to the home market.

CHAPTER V.

ARTIFICIAL WITHERING OF THE LEAF.

Machinery and Apparatus for Limping, Wilting, or Withering the Leaf by Artificial or Mechanical Means—The Dry Warm Air System—The Moist Warm Air System—The Vacuum System—The Waste Heat System.

MACHINERY AND APPARATUS FOR WITHERING THE LEAF.

Two main systems of mechanical or artificial wilting, withering, or limping are in use at the present time. In the one, warm air, specially heated in a furnace, is drawn by a fan over the leaf, which latter is thinly spread upon suitable trays; in the other or second method, the waste heat from the different machines used for drying and firing the leaf is employed in a practically similar manner.

The first system may, however, be further sub-divided into three methods of procedure, viz.:—The dry warm air system, the moist warm air system, and the vacuum system.

THE DRY WARM AIR SYSTEM OF ARTIFICIAL WITHERING.

The first of these methods—or that which is known as the dry warm air system of withering, and which will be primarily dealt with—has been objected to for the following amongst other reasons, viz.:—

That subjecting the leaf to its influence has a strong tendency to check true saccharine fermentation. There is a risk of the bursting of the cells being produced by too rapid an expansion of the fluids contained in them, and the consequent serious deterioration in the quality of the leaf. A considerable loss of aroma being caused by this bursting of the cells, and the aromatic principles

FIG. 15.—Dry Warm Air Tea Leaf Withering or Limping Apparatus (perspective view).

being in consequence chiefly located outside the leaves instead of inside them, in which external position these volatile aromatic principles will be more exposed to the action of the atmosphere, and liable to loss. The system is also more expensive than the other.

The dry hot or warm air system of withering in confined chambers produces, of course, much more rapid work, and this fact would, were there no counterbalancing objections, render it far and away the most advantageous, for there can be no doubt as to the convenience of being able to limit the withering accommodation to a chamber occupying but comparatively little space in the factory, and possessing a capacity for the withering or limping of a charge of leaf placed in it of about half an hour. In this manner the green or freshly-plucked leaves could be withered as fast as brought in, and passed on immediately to the rolling machine.

It is held by some authorities, however, that this system of withering, by rupturing the cells of the leaf, either destroys or alters the condition of the constituents requisite to the development, at a later period, of the aromatic principles. And it is, moreover, averred that the quality of the tea manufactured from leaf withered in this manner has been found to deteriorate very rapidly. On the other hand, it may be mentioned that the dry warm air system of artificial withering is claimed by many to have been found to give excellent results in practice.

The main features of most of the dry hot air arrangements for chamber withering are—a suitable furnace for heating the air, and one or more large exhaust fans, or other means, by which the air so heated can be drawn over the leaf, which latter is spread upon trays formed of wire mesh and supported upon wires stretched tightly across the chamber, the trays being placed in tiers about six inches apart. In fact, the apparatus does not differ materially from that intended for the drying or firing of the tea, and a number of machines are claimed to be equally applicable for both operations.

Many different arrangements have been devised for the artificial or mechanical withering or limping of the leaf by means of dry warm air, some of which will be now briefly described.

Figs. 15 and 16 illustrate a patented system of withering or limping tea-leaf which has been devised by Mr. Edward Robinson,

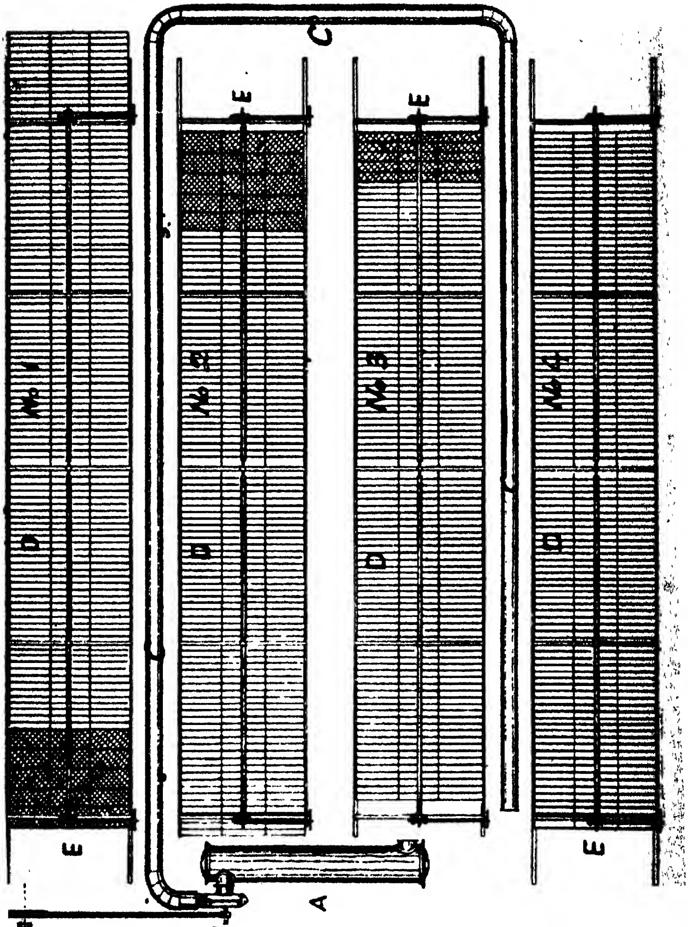


FIG. 16.—Dry Warm Air Tea Leaf Withering or Limping Apparatus (plan view).

T.M.

London, by means of which very favourable results are reported to have been obtained in actual working. According to the inventor, an installation of this withering system has been working at the Meddecombra tea estate in Ceylon for about eight months, and the managers and engineers who have from time to time tested the working have, in independent reports, certified the following results to have been established, viz.:—That good tea can be made during continued wet weather when, with only natural withering, such tea would be spoiled. That the tea withered by this system, in wet weather, has been shipped to the London market, and sold at the same price as other teas which had been withered naturally under favourable conditions on the same estate. That the trays can be filled, and the tea withered off four times in each twenty-four hours. That the apparatus works well in all respects, and the withering is uniform in all parts of the room alike, the wind being equally dispersed, and the heat—which is under perfect control—can be maintained at any desired point from atmospheric temperature to about 120° Fahr. That for natural withering in fine weather the trays have been continually used, without heater or fan, the result being the same as that obtained by withering on ordinary tats or chungs.

Fig. 16 shows a plan of a withering or limping floor, arranged on the Robinson patent system ; of course two or more floors of trays may be placed the one above the other. Referring to Fig. 16, A is a tubular steam heater, B is a close exhaust pressure fan, C is an air distributing pipe for the equal dispersion of the hot air, D are the wire trays upon which the tea-leaf is spread, E is the winding gear.

The trays D upon which the tea-leaf is spread are about seven feet in length by five feet in width, the exact dimensions varying, however, in accordance with the size of the room; they are constructed with a frame of round iron covered with wire netting, the whole arrangement being galvanized. These trays are attached by means of hooked bolts to two parallel bars of angle iron, so that they swing over from one side to the other in a manner practically similar to the leaves of a book. Ropes are attached to the trays at the sides opposite to the hinge-like attachments and to a continuous roller or

windlass mounted overhead, and supported by angle iron uprights, as shown in Fig. 15, which view depicts a set or row of sixty wire trays mounted on angle iron framework. Below the trays is placed a sheet conveyor. The roller or windlass can be operated by a chain and chain wheel through worm gearing, as shown on the left-hand side of the drawing, and by its means a boy can easily raise an entire row or set of trays at one time.

In the plan view, Fig. 16, D No. 1 indicates the trays reclining backs upwards, ready for turning over one by one to spread the leaf; D No. 2, trays reclining faces upwards, as when leaf has been spread ready for raising up; D No. 3, trays raised to an angle of forty-five degrees, as when the withering or limping process is going on; D No. 4, trays standing in a perpendicular position, as when dropping the leaf upon the sheet or conveyor below.

On commencing to spread the leaf the entire row of trays is placed in the position shown in D No. 1, in which the trays recline on each other, backs upwards. The first tray of the series is then turned over by hand, and the leaf spread upon it, the same operation being performed with the rest of the trays in succession. As there is a gangway on each side of the trays, the leaf can be spread from both sides at the same time as the trays are turned over.

As soon as the leaf is thus spread, a few revolutions of the windlass will raise the series of trays all up at once to any desired elevation, the leaf resting securely on the trays at an angle of forty-five degrees, or even more, and the trays being left suspended at about that elevation until the withering or limping process is completed. A clear open space of four inches is provided between each tray, thus admitting a free current of air to both sides of the leaf to carry off the moisture. When the wither is completed the trays are raised to a perpendicular position, and the leaf will fall from them to the sheet or conveyor below, which is attached to a roller and worked with a handle and light gear wheels. By this conveyor or travelling band or apron the leaf can be delivered at one end of the series or set of trays, and can be dropped through an opening in the floor to the rolling room, or picked up as desired. A row of sixty trays will pitch down 500 lbs. of leaf at one time, and the whole of it could be delivered to the rolling room in five minutes without any handling, the great saving of labour

thus effected being obvious, and being claimed by the inventor as being equal to 75 per cent.

The arrangement for the artificial heating of the air is shown in Fig. 16, and consists of a tubular steam heater A, which is connected to any available source of steam supply by means of a one-inch pipe, by which steam is admitted to the interior of the tubes, the air, which is drawn through the heater by the exhaust fan B, being caused to circulate round these tubes by means of a spiral diaphragm, during its course there-through. The air, being unmoistened by any escape of steam, can, if required, be raised to a high temperature, the degree of heat being, however, under perfect control, and capable of being modified to any required point which may be found to be the most suitable for producing the most effective withering.

The air heated in this manner is blown by the fan into an air-distributing pipe C, which pipe has a series of nozzles placed at equal distances apart along its entire length, and so arranged and proportioned as to disperse a volume of heated air under all the trays alike, cowls or other suitable outlet ventilators being provided on the top of the roof of the withering house or chamber, or, if this is not practicable, then as high up as possible therein, for admitting of the escape of the air after utilization. The current of heated air is confined within the area of the withering trays by curtains suspended upon the iron frame.

One air heater and fan is capable of working two withering or limping floors, in which case the floor of the upper chamber must be made of open lattice work, so as to admit of free access to it of the warm air from below. When drawn out the sheet conveyor covers the lattice work openings, and prevents any leaf from falling through during spreading or collecting, but during the withering operation it is wound in out of the way.

In a building of fifty-five feet by forty feet, with two floors, 500 trays can be arranged on each floor, or 1,000 trays in all, giving a spreading area of 35,000 square feet. The area of spreading space afforded by these swinging trays, in the same building, is more than twice that of the tats or chungs in Indian factories. This system can be arranged to suit any ordinary withering house, although it is, of course, more advantageous, when possible, to erect the building especially to suit the installation.

When required the trays can be used for natural withering or limping instead of ordinary tats, the fan being, when found desirable, worked without heat so as to assist the natural process.

A machine for withering, limping, or wilting tea-leaf, designed by W. Jackson, comprises an endless travelling band operating in conjunction with an open drum to form a rotary chamber, open at one side for the admission of the tea and of air from a fan. Both the band and the drum are arranged to carry battens or shelves for agitating the tea-leaf, and the whole is inclosed in a casing through which air can be drawn by an exhaust fan. To discharge the tea-leaf the motion of the machine is reversed.

In a withering or limping machine devised by W. A. Gibbs, the leaf is treated in a rotating cylinder, which can be heated either internally or externally by hot air passed through pipes from a furnace. The hot air is forced through two ducts and through perforations protected by louvres and by wire gauze respectively. Shelves arranged in the rotating cylinder operate to lift the tea-leaf and let it fall between the two air ducts.

Two forms of rotary apparatus for the artificial withering or drying of tea-leaf have been designed by T. Balmer, the first of which consists essentially of a wooden or metal cylinder formed in sections longitudinally to facilitate access to the interior, and provided with a lagging or outer covering of non-conducting material.

Fixed on the interior of this cylinder are a number of shelves, either straight or spiral and either continuous or broken, and a series of diaphragms. The upper end of this cylinder is mounted upon an adjustable end-plate or on rollers carried by the frame, and the lower end is provided with a trunnion, upon which is mounted a bevel or mitre wheel, through which rotary motion can be imparted to the cylinder.

To feed the leaf into the cylinder, a hopper is provided at the upper end of the latter, from which hopper the leaf is fed by a rotating drum actuated by a pawl and ratchet-wheels from the revolving cylinder, and having cavities by which the leaf will be carried down, other cavities at the lower end of the cylinder admitting of the final escape of the withered tea-leaf.

A current of air, heated by the exhaust steam from the engine or by a furnace, is caused to enter at the upper end of the cylinder,

and is driven through the drying chamber in the cylinder by a fan; or superheated steam, or other gas, may be employed instead of heated air.

The second machine comprises a cylindrical wooden chamber lined with sheet metal, a layer of some non-conducting substance being placed between the inner and outer shells. This chamber is divided into compartments by fixed rings, to which movable rings are so attached, by means of bolts and slots, that they can be rotated through part of a revolution through toothed sectors mounted on short spindles, and projecting into the interior of the drying or withering chamber so as to engage with circular racks mounted on the edges of the movable rings. The ends of the above-mentioned spindles being squared, admit of the necessary adjustment being effected by means of a key or spanner. Helical blades are also provided for lifting the tea-leaf, each of which blades consists of a metal piece attached by an angle iron to one of the fixed rings at one end, and to a movable ring at the other, in such a manner that a certain helical twist can be imparted to it by a partial rotation of the movable ring. By this means the helical twist of the lifters is capable of being adjusted to be least in the first division, and to increase as it approaches to the last division, so that the tea-leaf will be moved slowly through the chamber at first, and with augmented rapidity after it has become partially withered.

The hot air is driven through the drying or withering chamber in an opposite direction to the path taken by the leaf.

This apparatus is stated to be also applicable for drying the tea-leaf, in which case the hot air must be driven in the same direction as that in which the leaf travels through the chamber.

THE MOIST WARM AIR SYSTEM OF ARTIFICIAL WITHERING.

This system of artificial or mechanical withering, it is claimed, obviates the objection which has been made to the use of air specially heated for the purpose, in a furnace or stove, in the manner described with reference to the dry warm air system, inasmuch as the air used for withering purposes will become charged with moisture by a repeated circulation over the leaf. In this way the evils said to be attendant upon the use of

specially-heated air are avoided in this arrangement by using the same air over and over again.

The moist warm air system of withering, which is the invention of S. C. Davidson, is said to enable the proper withered condition of the leaf to be produced with practically no evaporation of the naturally contained moisture, and the leaf when thus withered is claimed, moreover, to produce a better quality of tea than when withered on the partial drying system hitherto in ordinary use.

The process consists, briefly, of subjecting the freshly-plucked or green leaf to the warming, but at the same time non-drying, influence of moisture-laden or nearly saturated air, at a temperature of 90° to 100° Fahr., the leaf being thus gradually limped or withered, without at the same time appreciably evaporating its naturally contained moisture. And the inventor states that as the cells of the leaf when thus withered will still remain well distended with their juices, and also retain a more delicate succulency of texture, they will be much more easily burst during the subsequent rolling process than would be the case with the cells of leaf which has been withered in the hitherto customary way, by the evaporation of from 20 to 50 per cent. of its moisture, which, he avers, will have the effect of causing its cellular tissue and the substances lining the cell walls to become shrunken and leathery in texture.

One method of producing this desirable form of wither is to expose the leaf to the action of a current, or circulation, of moisture-laden warm air, on trays, webs, or racks, suitably arranged for this purpose in a chamber or compartment, the sides, top, and floor of which are so constructed as to be as air-tight as possible, one or more inlets being provided for the warm moisture-laden air, which after circulating amongst the leaf in the withering chamber can pass out of it through one or more outlets, or through a heating apparatus, and be re-heated and returned into circulation in the withering chamber.

When such a withering room or chamber as that above described is employed, the trays, webs, or racks on which the green or fresh leaf is spread are preferably arranged in a similar superposed order to that used for withering the leaf by the ordinary evaporative system. The trays or webs can be conveniently carried in tiers, upon frames or racks, which may be either stationary or so constructed as to be capable of being moved on wheels, like railway

trucks, through a tunnel-shaped withering chamber, one before the other from end to end in consecutive order, perforated plates being preferably fitted at the inlet and outlet ends of the chamber through which the heated moisture-laden air has to pass from the distributing duct and the collecting duct respectively; or the leaf might be carried through the withering chamber on endless webs.

In another method of carrying out the process, a revolving drum or cylinder may be used, which is so constructed that when the inlet door for charging it is closed, it will be approximately air-tight except at each end, where an aperture is provided—that at one end for inlet and that at the other end for outlet of the circulating air current—and to each of which openings conduit pipes are so connected as to conduct the circulating air current from the drum or cylinder through an air-heating apparatus and fan, and back again into the drum or cylinder. Longitudinal shelves fitted upon the inside of the cylinder act to lift the leaf up to the top and then let it fall again as the drum revolves. The inlet and outlet ports are preferably connected by a tube of foraminous or perforated material, blocked midway by a baffle plate, which prevents the air passing straight through from the inlet to the outlet port, and compels the radial diffusion out from the inlet end of the tube towards the periphery of the drum, and back therefrom to the outlet side of the tube.

In order to keep the warm air in the withering chamber, or the withering drum, moisture-laden, like a vapour bath, and at a constant temperature of from 90° to 100° Fahr., conduit pipes connected with the inlet and outlet ports are provided for conveying the exhaust air of the withering chamber to and from an intermediately situated air-heating apparatus fitted with a fan, which draws the exhaust air from the withering chamber or withering drum, and causes it to pass through the heating apparatus and back again into the withering chamber or withering drum.

It will be seen that the same air circulated over and over again through the withering chamber or drum, in this manner, will rapidly get so fully charged or saturated with the vapour rising from the leaf, that it will soon become incapable of absorbing any further moisture, and, as this mixture of air and vapour is an effective conveyer of heat, it will act very satisfactorily in carrying the heat from the air heater into the withering chamber,

and keeping it up to the required temperature of 90° to 100° Fahr. Any arrangement of air-heating apparatus, such as steam, or hot-water pipes, or air-heating stoves, can be used for heating the circulating air current.

The air-heating apparatus can be arranged in any convenient position relatively to the withering chamber or withering drum, and might, if desired, be placed within the withering chamber, and so arranged that the cooled air from the latter will be conducted by suitable conduit pipes to the base of the air-heating apparatus, and the heated air conducted from the top of this up to near the ceiling of the withering chamber by means of an air chimney, so that a self-acting circulation will be thus created, and the chamber, having been rendered as air-tight as practicable all round, and the same air being heated and passed through the leaf over and over again, will consequently soon become vapour-laden through getting charged with moisture off the leaf, while at the same time sufficient heat will be imparted to it to keep the temperature thoughout the chamber up to 90° to 100° Fahr.

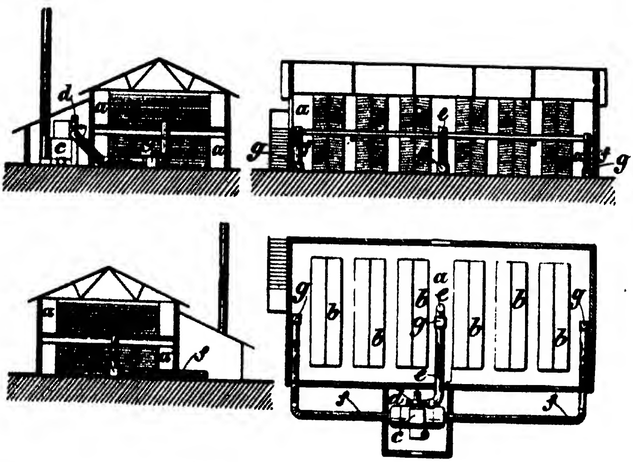
An alternative method of producing the above-described vapour-bath condition of the air in the withering chamber or drum, is to continuously propel into the withering chamber or drum, fresh, warm air charged with moisture by having sufficient steam injected into it to produce the necessary degree of saturation, or by passing it through a finely-atomised water spray, or through any wetted porous material or substance—such as wet cotton wool or wet tea-leaf in the process of being dried after being rolled—and allowing an equivalent quantity of this air to escape through exhaust ports provided in the withering chamber or drum.

Whichever method of warming the leaf in the withering chamber or withering drum by means of warm saturated air be adopted, very little evaporation of the naturally contained moisture in the leaf will take place; and when the heat of the chamber or drum is in this way continuously maintained at 90° to 100° Fahr., the leaf will soon begin to soften and become limp, and will, according to the inventor, eventually assume a much more flaccid condition than if it had been withered by the action of dry air.

Figs. 17 to 20 show an arrangement of withering chamber fitted with stationary racks for carrying the leaf upon trays or webs,

and with an externally situated air-heating stove and circulating fan, the latter being driven by belting or otherwise.

Two withering chambers *a*, the one located above the other, are shown, each of which chambers is fitted with stationary racks *b*, for carrying the leaf to be withered upon trays or webs. Outside the withering chambers is placed an air-heating stove *c*, and a fan *d*, which are connected with the withering chambers by an inflow air conduit pipe *e*, and by a return air conduit pipe *f*, each pipe being fitted with a box *g*, having ports, and valves or doors



FIGS. 17 to 20.—Arrangement of Moist Warm Air Withering Chamber with Stationary Leaf Racks and External Air-heating Stove and Circulating Fan (sectional elevation, cross sections, and plan).

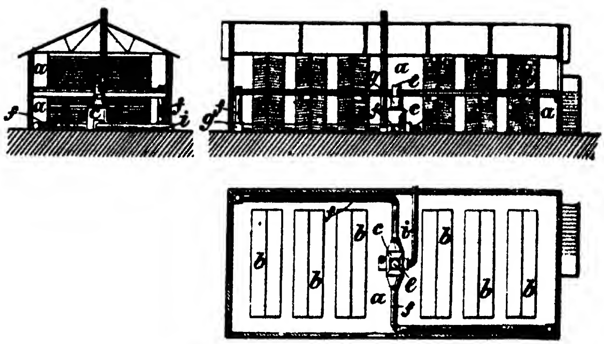
for opening and closing the same, so as to enable the circulating air current to be confined to either floor as required.

When the fan is set in motion, the air laden with the moisture it has taken up from the leaf will be drawn from the withering chamber through the conduit pipes and the stove, and be propelled back in a moisture-laden and heated condition into the same withering chamber through the inflow pipe.

Figs. 21 to 23 illustrate an arrangement in which the air-heating stove *c* is placed inside the withering chamber *a*, and works with a self-acting draught. The valve boxes *g*, connected

with the air inflow and return pipes *e* and *f*, and the ports or doors for opening and closing them, enable the circulating air current to be confined to either floor as may be required. To prevent the fire in the stove from drawing off any of the moisture-laden air from the withering chamber for the support of combustion, a supply of air is conducted to the fire from outside through a pipe *i*.

Figs. 24 and 25 illustrate an arrangement in which the racks for carrying the leaf are constructed to move on wheels, as trolleys or trucks, through a tunnel-shaped withering chamber *a*, whilst being subjected to the action of a current of moisture-laden heated air. It will be seen that the racks *b* are mounted on



FIGS. 21 to 23.--Arrangement of Moist Warm Air Withering Chamber, with Stationary Leaf Racks and Internal Air-heating Stove (sectional elevation, cross section, and plan).

trolleys *j*, which move in consecutive order on rails *k*, in the withering chamber *a*. *l* are perforated plates through which the heated moisture-laden air has to pass from the distributing duct *m*, to the withering chamber, similar plates *n* being also provided, through which the air will be exhausted back into a collecting duct *o*, at the outlet end of the chamber, and thence pass through the return pipe.

The trolleys with the racks containing the leaf enter the long tunnel-like withering chamber through the entrance doors *p*, which are made preferably to open inwards, so that when a trolley is pushed along the rails sufficiently far into the withering chamber

to clear these doors and allow of their being closed again, it will also be clear of the direct inflow of the air current from the distributing duct, and the space here left will enable the air currents to blend and mix uniformly before being passed along over the leaf on the trays carried on the trolleys in its flow to the outlet air ducts. *q* are the outlet doors, which are preferably made to swing outwards.

When the trolleys are drawn out of the withering chamber they can be turned on the turntables *r*, and can be then passed along the return rails to the inlet end of the chamber, and on their way they can be unloaded of the withered leaf and be re-charged with fresh leaf to be withered.

Another apparatus for withering tea-leaf on this system is shown in Figs. 26 to 28.

In this arrangement, the leaf to be withered is carried through the withering chamber *a*, upon endless webs consisting of flat or dished perforated plates or woven wire trays *u*, which are moved forwards and backwards in the withering chamber by endless bands or chains mounted on suitable wheels, and are moved by sprocket wheels driven by a suitable arrangement of gearing.

The leaf is fed into the apparatus through a feed hopper *v*, and is discharged by means of the chute *w*.

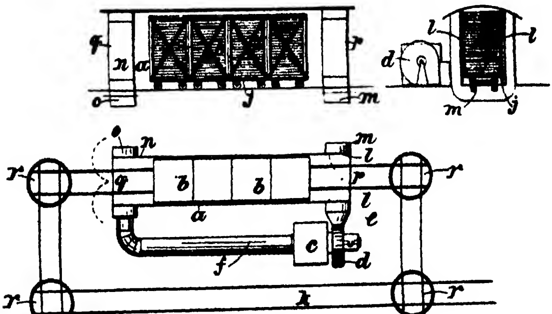
Air is drawn by the fan *d* from the withering chamber *a*, through the air duct *f*, and heating apparatus *c*, and the same air is again driven back into the withering chamber through the inflow air conduit pipe *e*.

In Figs. 29 to 32 is shown a rotating drum or cylinder withering apparatus *a* mounted and revolving upon standards to which are attached inflow and return air conduit pipes *e* and *f*, and a fan *d*, for circulating the air from the withering drum through the pipe *f*, and air-heating apparatus *c*, and back again into the withering drum *a*.

The withering drum is revolved preferably by means of friction rollers mounted upon a shaft, which is driven from a suitable countershaft by belt gearing.

The drum or cylinder *a* can be charged or emptied through a door or port *t*, and upon the inside a number of longitudinal shelves are provided for lifting the leaf up to the top of the drum before letting it fall again as the latter rotates.

The inlet and outlet ports are connected by a suitable tube a^*, constructed of perforated corrugated sheets, or of wire web, which tube is attached to and revolves with the withering drum. In this perforated tube, midway between the inlet and outlet ports, is placed a baffle plate, shown in dotted lines in Fig. 30, which prevents the air from passing straight through from the inlet to the outlet port, and compels the radial diffusion of the air out from the inlet end of the perforated tube towards the periphery of the drum and back to the outlet side of the tube, so that the leaf will be better brought into contact with the warm moisture-laden air, and there will be no tendency to carry the leaf in the air current from the inlet to the outlet port.



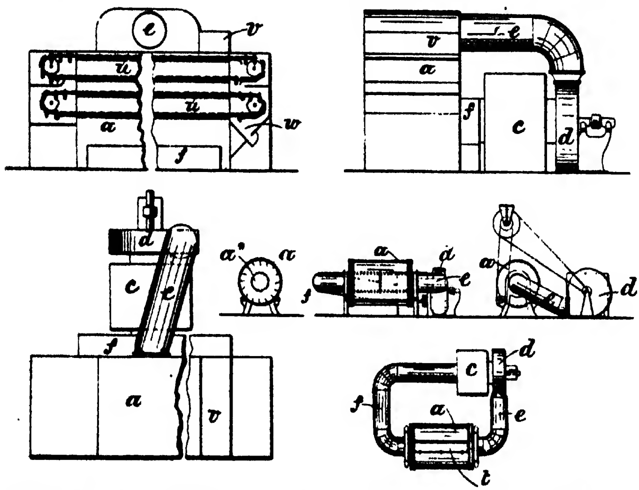
FIGS. 24 and 25.—Arrangement of Moist Warm Air Withering Chamber, with Leaf Racks Mounted on Wheels (sectional elevation, cross section, and plan).

In operating this machine, a charge of leaf is placed in the drum, and the latter rotated at the slow speed of from ten to twelve revolutions per minute, the fan being also set in motion, so that a continuous circulation of air will be immediately set up through the drum and air heater; and as the cylinder revolves, the shelves will carry up the leaf to the top of the drum, where it drops off, so that a continuous shower of leaf will be kept falling through the air current which is passing through the drum, which air current will soon become saturated, like a vapour bath, with the moisture from the leaf, the limping or withering of which latter will then take place in heated moisture-laden air, any appreciable

evaporation of the naturally contained moisture of the leaf being thus prevented.

It has been found desirable in practice to fit the drum or cylinder with perforated diaphragms, so as to prevent the tea being carried away. The inlet and outlet ports are in this case arranged to open into a chamber separated from the main body of the cylinder by the above-mentioned diaphragms.

To effect the complete discharge of the leaf from the drum or cylinder after the opening of the doors, the latter are made to open



FIGS. 26 to 32.—Arrangement of Moist Warm Air Withering Machines, with Travelling Webs and Rotary Leaf Container (longitudinal section, elevations plans, and transverse section).

inwards so as to form shelves, which will catch the leaf as the chamber rotates. Depending or hanging shelves are also fitted to the door, and perforated material is provided to prevent the leaf drifting with the air current.

It has also been found very desirable to admit a certain or regulated amount of fresh air, preferably in the latter part of the withering operation of each charge, so as to provide for a supply of oxygen to the leaf in order to oxidate it, because oxidation at this stage of the process of manufacture of black tea will considerably improve the quality obtained. Consequently, it has been

found advisable to so construct an apparatus that a quantity of the moisture-laden air, variable at will, can be discharged continuously or occasionally from the apparatus, and an equivalent volume of fresh atmospheric air be admitted in its place.

For this purpose the pipe through which the moisture-laden air returns from the withering drum to the air heater is fitted with a moist air outlet valve, by means of which a portion of the current of moist air as it flows at considerable speed through the pipe can be cut out; and a fresh-air inlet, also in the form of a valve, and likewise situated in the same pipe as the moist air outlet valve, is provided to admit a volume of fresh air equivalent to the amount of moist air discharged.

A good arrangement of valves for the above purpose consists of two flap valves fitted diametrically opposite to each other in the

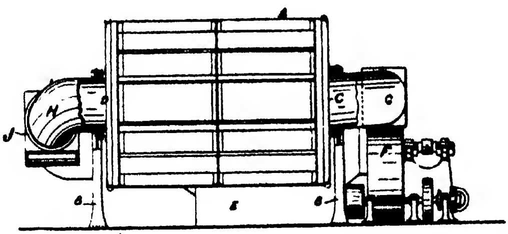


FIG. 33.—Moist Warm Air Withering Machine or Apparatus, with Rotary Leaf Container (sectional elevation).

wall of the said pipe, and so connected as to move together—the one forming the moist air outlet valve, opening inwards; and the one forming the fresh air inlet valve, opening outwards. The moist air outlet valve is hinged at the side which is furthest from the withering drum, so that when open it presents itself at an angle with its inner edge to the current of moist air, and consequently divides this current, causing one portion to pass through the opening of the valve and to be thus discharged outside the apparatus, whilst the remaining portion will pass on through the pipe to the air heater, being joined by a supply of fresh air which enters through the inlet valve, which may be also hinged like the moist air outlet valve. These valves are operated by means of a quadrant bar attached to one or other of them, this

bar having a series of holes or notches to engage with a pin or catch and allow of the valves being adjusted to any required extent of opening.

Figs. 33 to 38 illustrate an apparatus of this type. A is the rotating drum, which is mounted on standards B. C is the air inlet

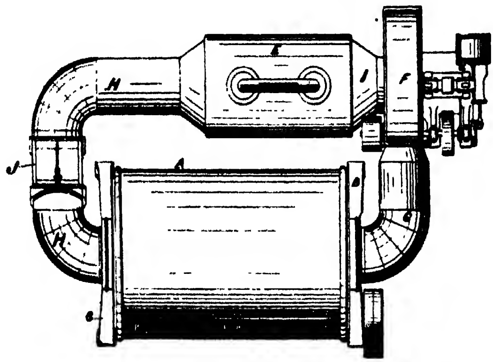


FIG. 34.—Moist Warm Air Withering Machine or Apparatus, with Rotary Leaf Container (plan).

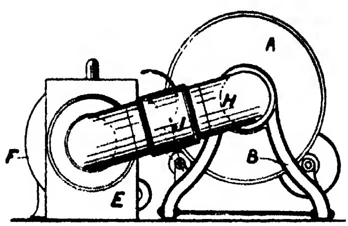
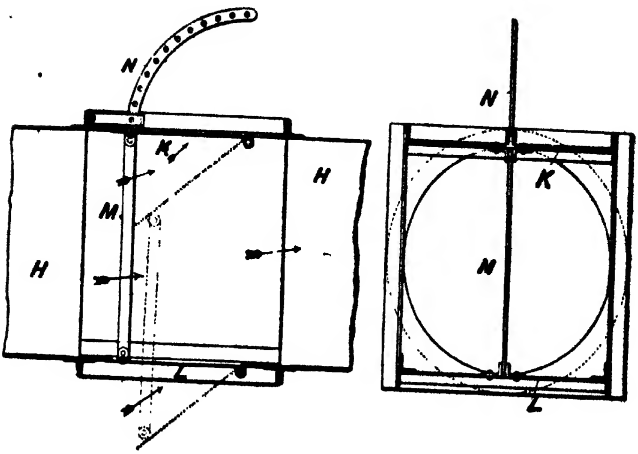
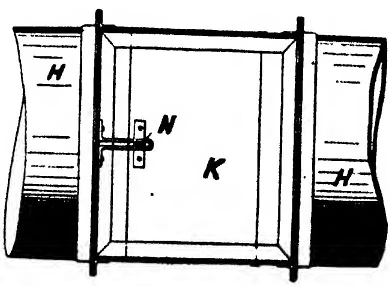


FIG. 35.—Moist Warm Air Withering Machine or Apparatus, with Rotary Leaf Container (end view).

port at one end, and D the air outlet port at the other end of the drum. E is the air-heating apparatus and F is the fan. G is the inflow air conduit pipe leading from the fan to the air inlet port C. H is the return air conduit pipe leading from the air outlet port D, to the air-heating apparatus E. I is an air conduit funnel or tube leading from the air-heating apparatus E to the fan F. J is a valve box, which is fitted in the return air conduit pipe H. K is the

cut-out valve for exhausting a portion of the circulating air from the pipe H, and L is the fresh-air inlet valve for admitting an equivalent volume of fresh air. M is a connecting link between the exhaust or cut-out valve K, and the fresh-air inlet valve L, by which these





FIGS. 36, 37, and 38.—Moist Warm Air Withering Machine or Apparatus, with Rotary Leaf Container (enlarged views showing details of construction).

two valves can be opened and closed equally and simultaneously. N is a quadrant by which the amount of opening given to the valves, K and L, can be regulated. See Figs. 36 to 38.

The valve box J is arranged to form part of the return pipe H, and the air current from the rotating drum A, to the heater E, and

fan F, will pass through it in the direction indicated by the arrows in Fig. 36.

In operation, upon the cut-out or exhaust valve H, and the fresh-air valve L, being worked, the former will open inwards, so that its edge faces the return air current, and will thus cut out of the valve box a certain quantity of air in accordance with the extent of opening which may be given to it—fresh air, equivalent in volume to that of the exhaust air thus removed, being simultaneously admitted through the fresh air inlet valve L, which, by means of the link M, which connects it with the exhaust valve K, will be opened outwards to a corresponding extent.

A recently designed pattern* of machine for effecting the withering of the leaf on this system is shown in perspective in Fig. 39.

It will be seen from this illustration that the machine is even more entirely self-contained than that which has been just described. It is also driven by its own special engine *a*, which is mounted on the bracket *b*, of the fan F. This arrangement is found to be very advantageous, inasmuch as it renders the apparatus entirely independent of any line of shafting for driving power, and admits of its being located in any conveniently situated outhouse or in any portion of the factory, so long as it is sufficiently near the main boilers, or an auxiliary boiler, to admit of steam being conveyed to the engine without an extravagant amount of loss of heat through condensation taking place.

The heat required for warming the air used for withering the leaf is supplied by the waste steam from the fan engine cylinder, which waste or used steam is for that purpose exhausted through the pipe *d*, into the tubes of a multitubular air-heating device *c*, so that no special furnace is required—the steam supply being, of course, usually obtainable from the boilers for supplying steam to the main engine of the factory.

This air heater likewise forms an air condenser, in which the exhaust steam will be entirely deprived of its heat by the air and vapour circulating through the multitubular heater, and in consequence will be so completely condensed into water that its full theoretical heating efficiency will be therefore utilised in the total amount of the work performed.

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* Made by Davidson & Co., Ltd., Belfast.

e is a bye-pass, which admits of the exhaust steam being cut off from the air heater, and being allowed to escape into the atmosphere or elsewhere, when desired.

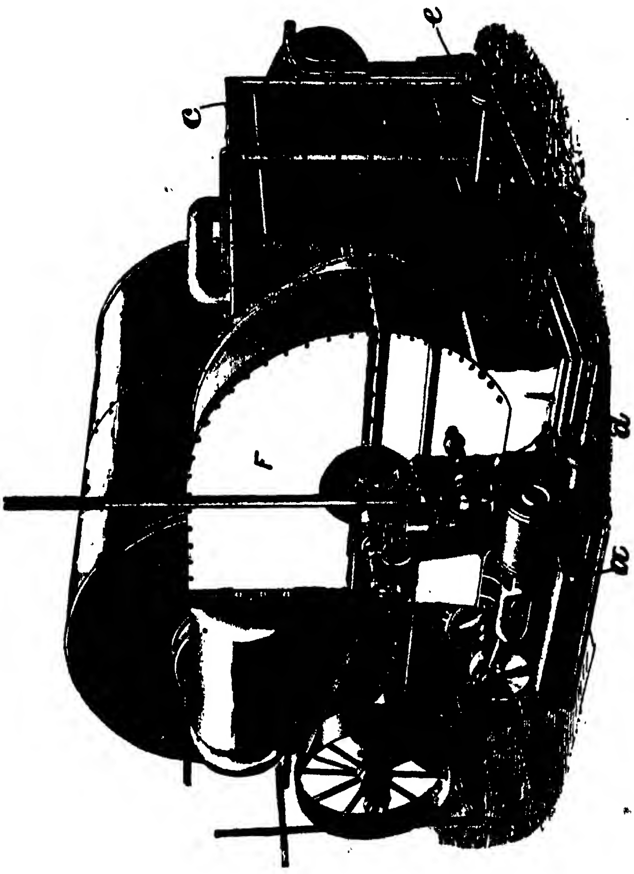


FIG. 39.—Recent type of Moist Warm Air Withering Apparatus, with Rotary Leaf Container

The cylinder or drum has a capacity which admits of a charge of about six maunds (480 lbs.) being inserted into it at a time, and one hour and a half is about the period required to effect the withering of a charge.

The operation of the apparatus is of the simplest description, all that is required being to throw the charge of leaf into the rotating drum A, and to start the fan engine *a*, which likewise drives the latter.

Warm moist air is then circulated through the leaf, only a small proportion of fresh air being admitted into it, and an equal volume thereof being exhausted, so that as it is circulated through and through the multitubular heater, fan, and withering drum, it will become rapidly charged with vapour owing to the evaporation of the moisture out of the leaf.

It is averred that not only is the withering of the leaf effected very efficiently and rapidly by this continuous circulation of moist heated vapour, in combination with the movement which is imparted to it by its being turned over and over upon itself in the rotating drum, but that the leaf also acquires at the same time an aroma or perfume of a peculiarly agreeable character.

The progress of the withering operation can be ascertained from time to time through suitable sampling ports fitted in the doors of the revolving cylinder or drum.

When the wither is found to be complete, and it is desired to discharge or remove the leaf from the revolving drum or cylinder, the machine must be stopped running, and the doors of the drum opened, and so secured by means of suitable fasteners that they will remain open; after which the machine should be again started, when the withered or limped leaf will be discharged through the opened doors as the drum revolves.

A feature of some importance in connection with this withering apparatus is that the leaf will be also partially rolled during the operation of withering, an effect due to the tumbling over and over to which the leaf is subjected in the rotating drum.

The Vacuum System of Artificial Withering.

Amongst the many other machines which have been devised for effecting an artificial wither of the leaf, mention may be made of those which are adapted to operate by subjecting the leaf to the action of a vacuum. It is to be remarked, however, that the amount of success by which their employment has been attended has not warranted any extended use of them.

In an apparatus for withering tea-leaf previous to rolling, by subjecting the leaf to the action of a vacuum or of a partial vacuum, which has been devised by J. C. Marillier, the leaves to be withered are placed on a series of galvanized iron trays, portions of the edges of which have been cut away so as to form air passages, and which trays are supported on brackets in an air-tight chamber fitted with a hinged door, which can be closed against an indiarubber ring or washer placed round the opening into the chamber, and can be held firmly in place by lever catches. This chamber communicates through a suitable pipe with a valve box, fitted with an air exhaust valve and with an air inlet valve, capable of being regulated by screw-threaded stems, rods, and handles, and which valve box is connected with an air pump, by means of which, when the air inlet valve is closed and the exhaust valve opened, a more or less perfect vacuum can be formed in the withering chamber, which vacuum is stated to produce the desired withering action.

When the leaf has been sufficiently withered, the exhaust valve should be closed and the inlet valve opened, after which the hinged door can be opened and the leaf removed.

ARTIFICIAL WITHERING BY MEANS OF WASTE HEAT.

The employment of waste heat possesses the advantage, as has already been mentioned, of creating a certain saving, inasmuch as by its use, at least when the drying and firing machines are in operation, no special expenditure of fuel will be necessary for heating the air required for the artificial withering or limping of the leaf.

There are two methods of utilising the waste heat—in the one of which exhaust fans are employed to draw the waste warm air through the withering or limping room or loft, and in the other blast fans or air propellers are used to force the said air through the room or loft.

The first arrangement is well exemplified in the withering system of the Blackman Ventilating Co., Limited, London, in which ventilating fans of the well-known Blackman type are employed.

Unless the building be especially designed in the first instance

with a view to an installation of the Blackman system of withering, the exact arrangement will, of course, have to be more or less modified in each particular instance to meet the space available in the factory—in fact, each case would have to be treated individually. In Figs. 40, 41, and 42, however, are illustrated three of the most simple forms in which the system can be applied when the building, position of dryers, and shafting, are all suitable to one or other of these forms. It must be remembered, however, that in a great number of instances there will be many other points which should be taken into account, and that, as a general rule, in all such cases it would be found preferable to get out a special plan of fixing to exactly suit the condition of things existing in the factory.

It will be seen by referring to the three illustrations that the room or loft is ceiled over above the racks in each instance, so as to confine the air current to its work. This is a very necessary precaution, inasmuch as the warmest, and therefore most useful, air always rises to the top, and would otherwise become for the most part lost and wasted in the space situated immediately beneath the roof, as well as being cooled by contact with the iron roof in cold weather and by its admixture with the cold external air which will be sucked in through the more or less open joints of the sheets of the roof.

The proper height for the ceiling cloth will depend upon the size of the fans employed. For instance, when 48-inch Blackman fans are used, the height should not be more than 6 feet 6 inches above the level of the floor of the withering or limping room or loft; but with 60-inch Blackman fans, the height may be increased to 8 feet above the floor level.

It has been found in practice that it is preferable in all cases where possible to draw the air across the room or loft in the manner shown in Figs. 40 and 41, inasmuch as the temperature of the air will be more uniform when drawn the shorter distance than when it is drawn the longer distance, and in consequence the wither will be also more uniform or even in quality.

The arrangement illustrated in transverse section in Fig. 40 is an application of the Blackman system of withering to an ordinary tea house having a ridged roof. The number of exhaust fans employed will, of course, depend upon the length of the withering loft.

In case the space at disposal be not sufficient, an addition to it can be provided with but little difficulty by erecting a lean-to extension, as indicated in dotted lines in the drawing, the same fans and the same air current in that case serving both the main room or loft and the extension.

The heated air from the drying and firing machines is drawn up through an aperture in the ceiling of the machine room, which ceiling should be constructed of some incombustible material, into and through the withering room or loft, and is discharged or exhausted either into the atmosphere or into the extension shown in dotted lines, as the case may be.

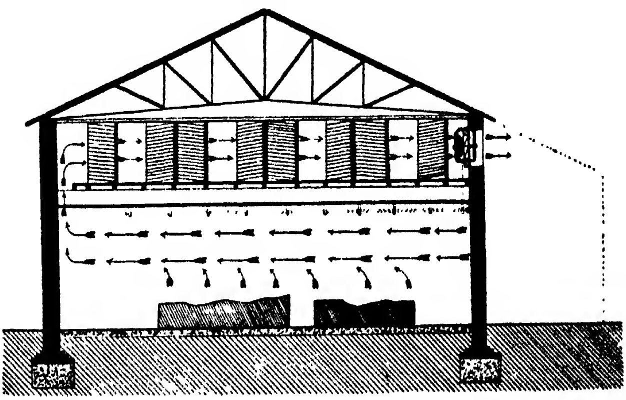


FIG. 40.—Application of Artificial Withering by means of Waste Heat to an Ordinary Tea House with a Ridged Roof (transverse section).

Below each of the fans and above the racks, situated in the lean-to extension, should be fixed an openwork hurdle about six feet in width, extending horizontally from the main wall of the factory to the opposite low side wall of the lean-to extension, so as to form a kind of baffle that will break the force of the draught or blast in a downward direction, and so prevent the leaf from being blown off the top trays.

Exits for the air from the lean-to extension should be situated at both its ends, both the side walls being well closed so as to force the current of hot air to flow down the entire length of the extension, and the racks may be arranged lengthways of the latter.

The roof ends of the lean-to extension should also be closed down to about four inches above the level of the uppermost trays in the racks, so as to cause the hot air to pass downwards through the racks and prevent its escaping to waste at too great a height.

Fig. 41 is a similar view to the previous one, depicting an installation of a like nature, but arranged in a tea house having a curved roof instead of a ridged one, the roofs in both instances being formed of corrugated galvanized sheet-iron. The description

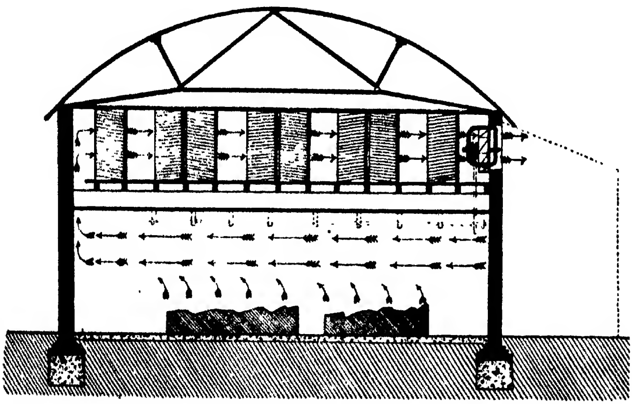


FIG. 41.—Application of Artificial Withering by means of Waste Heat to an Ordinary Tea House with a Curved Roof (transverse section).

given of the first arrangement applies with equal appropriateness to the present one.

When the withering racks are already arranged across the room or loft, and it is not desired to incur the expense of altering them to allow of the arrangement shown in Figs. 40 and 41—which, however, is in every way preferable—being adopted, or in such cases as where the machine room happens to be located at one end of the factory building without any floor above it, the plan shown in the longitudinal section, Fig. 42, may be adopted. If this arrangement be used, however, it is essential not to draw the air for a distance of over seventy feet down the loft, and in lofts or rooms of any considerable length it will be found better to place

the fans at each end (if they cannot be placed along one side), and

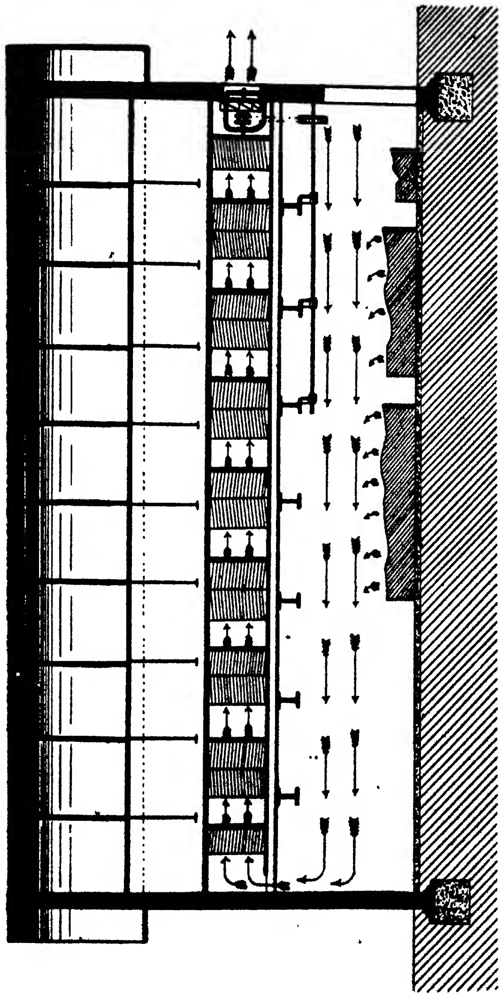


FIG. 42.—Application of Artificial Withering by means of Waste Heat where the Racks are arranged across the Room or Loft (longitudinal section).

to draw the hot air up through an inlet across the centre of the loft or room floor.

When the loft or room is over thirty feet in width, two 48-inch Blackman fans should be used, and the length of the loft or room must also be taken into consideration in estimating the number of fans required.

The most advantageous method of driving the above-mentioned fans is in pairs in the manner illustrated in Fig. 43.

The power required to drive a 48-inch Blackman depends, of course, upon the velocity at which it is running, and ranges from less than ½ to 2 h.-p. In practical working, however, the fans will very infrequently, if at any time, be required to be at full work when the tea-rolling machines are, for it must be remembered that the tea-rolling machines cannot be started until some of the leaf is withered or limped, which will naturally be that nearest to the hot-air inlet, and by that time the rest of the leaf

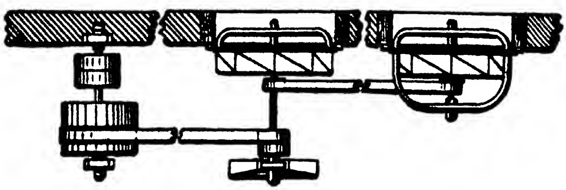


FIG. 43.—Most advantageous Method of Driving Fans in Withering Loft or Room.

will be so far finished that the speed of the fans may be considerably reduced, and will therefore only require a fractional horse-power for driving.

According to the makers, a 48-inch Blackman fan should never be run at a speed over 600 revolutions per minute, and 500 revolutions would be a more economical speed. The 60-inch should never be run at a greater speed than 480 revolutions per minute, and 400 revolutions would in the latter case be the better speed. The correct speed at which to run the fans will, however, vary to a certain extent, according to the state of the weather and of the leaf.

The maximum speed will most probably only be necessary when the leaf is brought to the factory in a moist condition and when the air is very damp. When the air is very dry, a slow speed of the fans will most likely be found to suffice, and it is

at these times when the air is excessively dry that great care must be taken not to run the fans at too high a velocity, or else the wither may become artificial or false, the colour of the leaf and fermentation suffering in consequence; for it is well known that to carry out the process in a satisfactory manner Nature can only be assisted, and not be coerced or forced, and if anything more than the withdrawing as far as possible of all obstacles to withering be attempted, loss of quality will result.

The correct speed of the fans most suitable to the varying conditions of the leaf and of the weather can only be ascertained by practical experience with each particular installation; and when this has been once acquired, the exercise of a little discretion will enable the proper withering of the leaf to be easily effected.

The best way to regulate the speed of the fans is to arrange for driving them by means of a separate engine; but when this is not done, three driving pulleys of different diameters should be placed side by side on the driving shaft and on the driven shaft respectively, so that the speed may be instantly altered to suit the conditions of the weather. This latter arrangement, however, necessitates the addition of an extra length of spindle to the fan and shaft.

As regards the number of fans required, a withering room or loft 100 feet by 40 feet should have four 48-inch Blackman fans if there be a sufficient supply of waste heat, and these fans can, by a suitable arrangement of ducts, be made to suffice for two such floors, where a second one is attainable. Where only one floor 100 feet by 40 feet is available, it should be capable of withering 8,000 lbs., or 100 maunds, of leaf in five hours in wet weather. With two such floors, about half as much again per day can be counted upon as will be the case with the one floor; double the amount of leaf cannot be withered by reason of a considerable amount of the heat of the air being lost before it reaches the upper loft or room.

It would, of course, be impossible to state the exact quantity of leaf that a 48-inch fan will be capable of withering in a ten-hour working day, as it will vary with both the nature of the building and also accordingly as to whether or not the temperature of the withering loft or room can be maintained above 86° when the fan or fans are running at a speed of 500 revolutions per minute.

Under favourable conditions, however, as regards the arrangement of the buildings, &c., a 48-inch Blackman fan has been found capable of withering 3,600 lbs., or 45 maunds, of wet leaf in a day of ten hours at only two fills of the trays—that is, the morning's leaf forming one fill and the evening's leaf the other fill.

Three similar fans are said to have been found to easily wither an average of 5,280 lbs., or 66 maunds, of leaf in three and a half to four hours, all the leaf of a half-day's pluck, however, in this instance, not being spread at one time, but the trays being refilled as fast as emptied from leaf stored for the purpose in a go-down.

It will be readily seen that in order to insure a wither throughout the loft or room of an even or uniform quality, it is more judicious to divide the work over several fans rather than to trust to one fan only.

In the latter case, indeed, not only would any accidental stoppage of the fan entirely arrest the operation of withering, but in any case the single fan having to draw the current of hot air lengthways down the loft and thus giving it a long distance to travel, during the whole course of which it will be taking up moisture, it is evident that the air at one end of the loft or room will wither the leaf at a more rapid rate than it will be possible for the saturated and cooled air at the other end to do, thus producing an uneven quality of wither.

By using a suitable number of fans in accordance with the length of the room or loft, and drawing the air across the latter, on the contrary, the distance travelled by the air over the leaf will, as has been already mentioned, be much less, and the state of the air more uniform in consequence, thus insuring a more even or regular wither.

The air should be admitted at the inlet side of the withering loft or room at a temperature some degrees above that absolutely required, so as to allow for the loss experienced in travelling to the other or exhaust side of it.

When drawing air across a loft in this manner, 48-inch fans should be placed from 25 feet to 30 feet apart, in accordance with the width of the loft. The end fans should not be situated at a greater distance than from 12½ feet to 15 feet from the end of the racks. These latter should be so arranged that the trays

containing the leaf, or the cloths or tats, if the latter be employed, will have a slope or be placed aslant, as shown in Figs. 40, 41, and 42 (and not be placed in a horizontal position), so as to deflect the current of air, and thus to bring fresh air in contact with the leaf, and produce a more uniform or even wither throughout the loft.

This arrangement also saves the waste of heat which otherwise would take place were the trays to be placed horizontally, by reason of the major portion of the centre of the air films passing through between the trays and doing actually no work at all.

If stretched wires are used for supporting the leaf trays, they need not be more than four inches apart. When, however, wires are not used, the distance must be increased so as to secure a distance of four inches clear space between the trays. There should not be any larger space above the uppermost tray or below the lowermost tray than there is between the other trays, as the air will travel best through the freest passage, and consequently the trays having the larger space be the first to wither, thus producing an uneven or irregular wither, instead of all the trays in the rack withering uniformly together from top to bottom, as with moderate care they may be caused to do, by having the spaces between the trays equal, or by employing baffles to check the current wherever it may be excessive, and to guide and deflect it in any desired direction.

In a well-arranged installation each rack should wither in turn, according to its proximity to the hot-air inlet, and no selecting of trays be required, but once a rack be declared ready, it will be fit to clear without any chance of unwithered leaf being mixed with that properly withered, so as to spoil the roll.

As regards the proper area for the hot-air inlet opening in the floor of the loft or room, or of any duct or thoroughfare through which the air has to pass, it must in no instance be less than the combined area of all the fans in use. For instance, for each 48-inch fan that is in use, at the very least 12½ square feet of free opening for the admission of air must be allowed; and if an inlet aperture of such a size be not provided, the fan will be hindered, and will not do its full work. Indeed, the makers recommend an allowance of 16 square feet of inlet for each 48-inch fan in use.

It is also advisable, in cases where doors are provided on the

first floor, which are necessary for traffic and which tend to admit fresh air in an improper manner, to erect a porch and add a second outer door, thus enabling one of the doors to be always kept closed, and thereby to check any improper admission of fresh air; and in order to prevent any possibility of the two doors being opened together, it will be well to fit them with a rope so arranged that to open the one door the other one must be closed.

It is especially advisable, in cases where the fan may be fed by a pipe or duct, or air be conducted away from it in such a manner, to see that such pipe or duct be not in any part of a less diameter or area than the fan itself. If a duct or pipe be employed which is of less area at any point than that of the fan, or that be throttled in any way, the horse-power required to drive the fan will be enormously increased, the amount of air drawn or moved towards the fan will be greatly reduced, and a back draught will be formed through the centre of the fan.

In practice, no duct to or from a 48-inch fan should have a sectional area of less than 14 square feet, and, wherever possible, 16 square feet would be far preferable.

Instances are on record in which planters have attempted to force air from a 48-inch fan through a 12-inch pipe or duct, when a 14-inch fan blowing into a 14-inch pipe would do about the same work, and the power consumed in driving a 48-inch fan throttled in such a manner would be about five times that which would be necessary under proper conditions, or from 2½ to 10 h.-p., whilst that required for the properly fixed 14-inch fan doing the same, or approximately the same amount of work, would be only about one-fifth of a horse.

The air admitted to the withering loft or room should be all drawn through the waste-heat inlet, and not from elsewhere, and external air should only be admitted to the machinery room behind the dryers and firers, that is to say, in such a manner as to have its temperature suitably raised before it reaches the hot-air inlet to the withering room or loft.

The position of the inlet for the warm air into the withering room or loft should always be at the floor level, and extend for the entire length of the withering racks. In some cases this will necessitate the use of double partitions to form air chambers. It will also be in all probability desirable to provide baffles in

the majority of cases, but these will have to be arranged to suit the requirements of each particular installation, and no fixed rule can therefore be laid down for their location.

When the dryers, firers, &c., are placed at one end of the machine room and directly beneath the withering loft or room, the inlet for the heated air from the former to the latter may be constructed tapering, so that the narrowest portion of it will be near the warmest end of the house and the widest end at the coldest end of it, thus regulating the supply of warm air and aiding in the production of a uniform or regular wither.

To admit of the inlet being adjusted to the proper proportions, the aperture should be made considerably wider than is necessary and of equal width all along, and loose, adjustable planks should be provided for forming the taper and adjusting it to the proper proportions.

In a withering room or loft in which three or more fans are employed and are fixed in the side wall, it will frequently be found desirable to throw one or more of the fans out of gear, and in this case that portion of the hot-air inlet corresponding with the fans which are not working should be closed, so as to allow of all the warm air being employed in that portion of the room or loft actually in use, and not being wasted by passing over empty racks, and also to effect a saving of the power which would otherwise be required to drive the temporarily useless fans. This can be easily done by providing hinged flaps or covers, as shown in the sectional view, Fig. 44, by means of which the hot-air inlet corresponding to any fan or section of fans can be closed. With this arrangement a countershaft and loose pulleys should be provided for enabling the rotary motion of any fan, or section of the fans, to be arrested when desired.

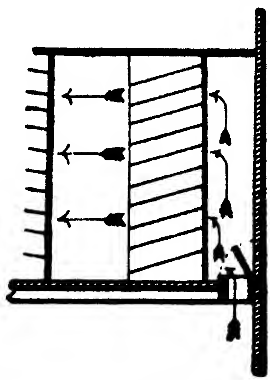


FIG. 44.—Arrangement for Regulating the Admission of Warm Air to Withering Loft or Room.

Another advantage possessed by the hinged flaps or covers shown in Fig. 44 is, that by setting them at any suitable angles

any particular portion of the air current can be deflected as may be found to be desirable. For instance, should the entire current, or any section of it, be found to strike certain of the trays in the withering racks more than others, or in a case in which the air is found, owing to its natural tendency, to rush or ascend directly up to the ceiling cloth or chut, and thereby to effect a more rapid withering of the leaves upon the upper trays than of those upon the lower ones, then the hinged flaps or covers can be so manipulated as to remedy this defect.

For ceiling cloths or chuts, and also for cloth stops for the tops

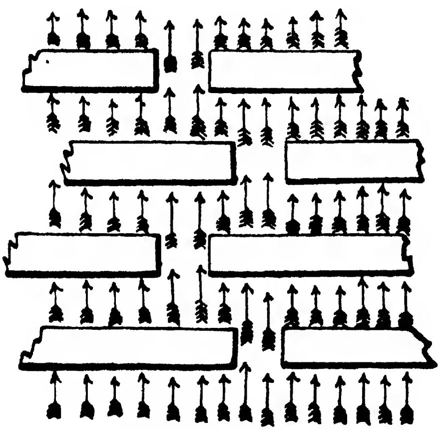


FIG. 45.—Diagram showing Method of Arranging Racks in the Withering Chamber or Loft.

of walls and for forming partitions, &c., old withering cloths thoroughly soaked in rice water, or otherwise sized so as to enable them to take a subsequent coating of whitewash, will be found very useful.

Where a second floor is situated above the withering loft or room, a ceiling cloth or chut will not be required, but in all other cases it is an absolute necessity. When a second floor exists, but is at too great a height above the first, the air current may be kept down to the proper level by cloth baffles or curtains suspended from the upper-story floor to within 6 feet 6 inches of the

floor level, if the fan or fans be 48-inch, or to within eight feet if the fan or fans be 60-inch, in a direction across the air current. The trays should be carried up to within four inches of the bottoms of these hanging baffles or curtains, and the distance or clearance between all the other trays in each of the racks should be the same as that between the uppermost tray and the bottom of the baffles.

When the gangways or passages between the racks come in line with the air current, curtains will have to be provided in order to prevent the hot air from travelling uselessly to waste

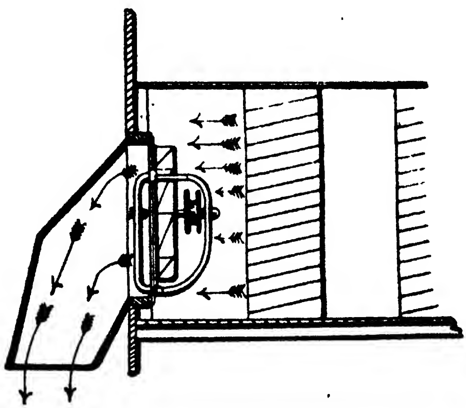


FIG. 46—Protective Shield or Guard for Delivery Side of Fan situated in an Exposed Situation (vertical longitudinal section).

down these gangways or passages. But what is a far better plan, and one which is recommended by the makers of the type of fans the use of which is now being principally discussed, the air current may be baffled by extending the ends of each alternate rack in the manner shown in the diagrammatical view, Fig. 45, upon which view the direction of the air current is indicated by the arrows.

Where the delivery side of the fan is situated in an unsheltered situation, thus rendering it liable to exposure to strong winds and to a consequent probability of the delivery from the fan being choked thereby, a wind guard or shield, such as that shown in the

sectional view, Fig. 46, should be fixed over it for protection. The size of the orifice of this wind guard, however, must be always at least equal to the area of the fan.

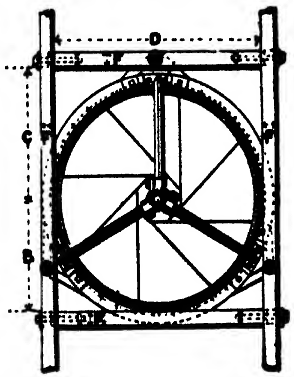


FIG. 47.—Front Elevation, showing the Seating Timbers required for Fixing a Fan of the Blackman Type.

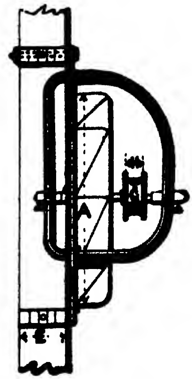


FIG 48.—Side Elevation, showing the Seating Timbers required for Fixing a Fan of the Blackman Type.

Figs. 47 and 48 show the seating timbers required for fixing fans of the Blackman type, and the subjoined table gives the dimensions necessary for different sizes of these fans.

A Diameter of Fan.	B Centre to Face.	C Centre to Face	D Between Timbers.	E Width of Deal.	F Thickness of Deal.	G Diameter of Pulley.
in.	ft. in.	ft. in.	ft. in.	in.	in.	in. in.
24	1 1	1 3⅞	2 3	6	2½	4
36	1 7½	1 11¼	3 4	9	3	6 and 7
48	2 2	2 6¼	4 4	11	3	8 „ 9
60	2 8¾	3 2	5 5½	12	4	10 „ 12
72	3 3¼	3 9⅞	6 5¼	12	4	12 „ 14

If necessary to suit the drive and to maintain the belt clear of the arms, one of the latter with its fixing bracket may be located over the centre of the fan, as shown in the drawing, or may be fixed horizontally on either side, as may be found to be the most

convenient. It is highly advisable, when fans linked in sets and self-driven are employed, on account of the strain on the axles of the first fans in a set increasing in proportion to the number of fans driven from each axle, that every fan in a set, except the last one, or pair, should have its axle supported by an A-frame standard bearing with plummer block.

An important point to be attended to in erecting the fans is to see that their blades be in no case located within the wall, but are always so placed as to project into the room quite clear of the wall. If this latter point be not attended to, the value of the periphery flange will be lost, and the air will not be drawn from all sides, as would otherwise be the case.

In conclusion, it may be remarked that a considerable proportion of the tea houses have been built so as to provide for a very extensive withering loft or room over the machine room, so large indeed that, were the whole of it to be employed, it would be objectionable—an evil usually aggravated by the correspondingly large proportions of the machine room underneath causing the waste heat in it to get too much diluted with cold air before passing up into the withering room or loft. Thus these ample areas frequently greatly increase the difficulty of insuring successful working, especially in cold weather. Wherever this is the case, proper precautions must be taken to provide, when establishing an installation for artificial withering, only sufficient accommodation for the work to be done, without a great excess of space, which latter would only reduce the warmth available to a deleterious extent.

The exhaust or used air from a machine for drying the tea can also be utilised for limping or withering by conducting the air from the exhaust port of the drying chamber into another drying chamber of practically similar construction, and driving or forcing it through the trays located in this second chamber, so as to limp or wither the green or freshly-plucked leaf placed upon them, the moderate temperature and slight moisture of the exhaust or used air being claimed to render it very suitable for the purpose.

In alternative arrangements the exhaust or used air is, in the one case, led into an air duct, the top of which is closed by perforated plates, over which one or more rows of sieves or perforated trays are so arranged that the air issuing from the air duct will

pass up through the trays, and limp or wither the green leaf on

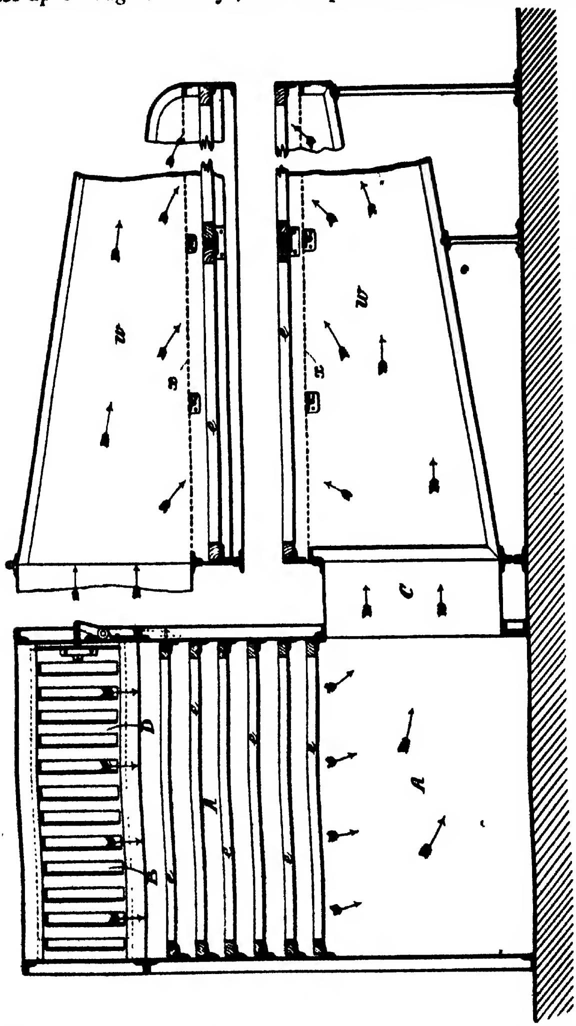


FIG. 49.—Apparatus for Utilising the Exhaust Air from a Drying Machine for Limping or Withering the Leaf.

them. And, in another case, the arrangement is such that some of the air will pass up through the perforated plates, trays, or

sieves, and some of it will flow down through other sieves or perforated plates.

Fig. 49 shows an arrangement of this description devised by S. C. Davidson. In this drawing, A is the drying chamber; B is the inlet port for the heated or desiccated air; C is the outlet or exhaust-air port; D is a gridiron valve for controlling the passage of the air through the inlet port at the top of the drying chamber; *w* is the withering or limping apparatus or chamber, which is connected with the exhaust port C of the drying chamber by an air duct as shown; *x* is a perforated plate for distributing the air draught; *e* are the perforated trays or sieves.

When the air draught is caused to pass down through the trays or sieves *e*, the air duct, perforated trays or sieves, and the air distributing plate *x*, are arranged as shown in the view in the right-hand top corner of the drawing.

A full description of the drying apparatus A will be found on pages 197 and 198, referring to the illustration Fig. 105. In the present instance, however, the dryer is intended to be worked with an air current driven under pressure into the top of the drying chamber, and the regulating valve D is consequently arranged above the trays *e*, instead of below the latter as in the machine shown in Fig. 105.

CHAPTER VI.

MACHINES FOR ROLLING OR CURLING THE LEAF.

Various Types of Machines in Use—Double-acting—Single-acting—Miscellaneous.

As good rolling forms one of the necessary details of the process of manufacture, it is important that a careful selection be made of the best form of machine for this purpose.

VARIOUS TYPES OF MACHINES IN USE.

The earliest successful machines for rolling or curling the tea leaf were designed by W. and J. Jackson, and the improved forms of their machines still hold a leading place, although many other excellent ones are now made.

The principle upon which the best known and most successful of Jacksons' machines work is that of superposed rolling plates, to each of which motion is imparted by compound or double cranks. These machines are fitted with six different types of rolling surfaces to meet different requirements, viz.:—1st, wood-faced under table, wood concave upper plate, and wood-lined jacket or case, &c.; 2nd, wood-lined jacket or case, with brass round the lower edge, brass pieces fitted into the corners of the jacket or case, and ventilated convex cap; 3rd, granite-faced table, brass-faced recess and trap door fitted with brass battens, wood-lined jacket or case with brass lower edging, brass corner pieces, and ventilated convex cap; 4th, brass-faced table, brass battens, brass lining to jacket or case, iron feed hopper with swing door, and ventilated convex cap; 5th, granite top plate and granite-faced under table, concave cap cut in granite; and 6th, and lastly, granite-faced table, brass-faced recess and trap door fitted with

brass battens, brass-lined jacket or case, brass corner pieces and ventilated convex cap.

In Figs. 50, 51, and 52 are illustrated three of the most recent patterns of Jacksons' tea-rolling machines, which are built by Marshall, Sons & Co., Limited, Gainsborough. That shown in Fig. 50 is a square-pattern machine, and is made in two sizes, the larger 32-inch and the smaller 24-inch. As will be seen from the illustration, it comprises a triangular framing of massive proportions, which is mounted upon three standards, one of which

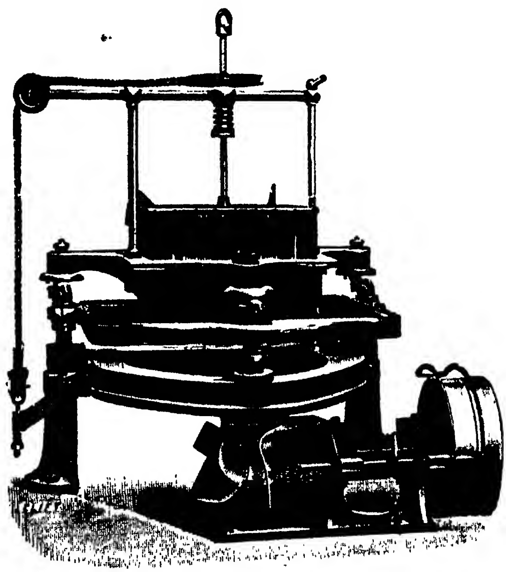


FIG. 50.—Square-pattern Double-acting Tea Leaf Rolling Machine.

carries the driving pulleys and a small bevel pinion; and the three crank shafts are also rotatably mounted in bearings in these supports, the one being the driving crank and the two remaining ones serving merely as guiding cranks.

The lower plate and the jacket or case, which contains and transmits motion to the upper one, is also carried by these crank shafts, and it will be seen that the entire mechanism is of the simplest possible construction, and that both plates are operated.

The leaf is discharged through a trap door in the lower table in the manner usual in this type of machine.

In order to admit of the driving pulleys being placed at will either on the right or left-hand side of the machine, the bracket or standard carrying them is pivoted into the triangular frame, thus allowing the pulleys to be placed on the one or the other

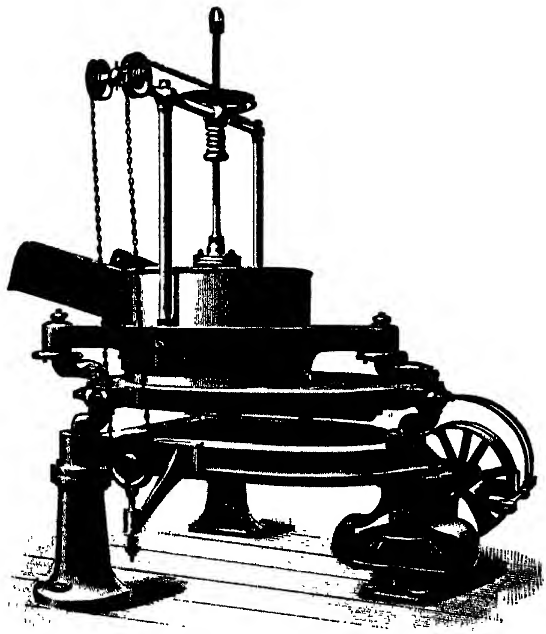


FIG. 51.—Circular-pattern Double-acting Tea Leaf Rolling Machine.

side, or half way round, as may be found to be the most convenient for driving.

The pressure on the leaf that is being rolled can be regulated by suitable screw gearing, and can be very conveniently adjusted from the floor by means of the endless chain shown, which runs over the pulleys at the side of the machine, thus being under the complete control of the operator.

The capacity of the 32-inch machine is 300 lbs. of withered leaf,

and that of the 24-inch machine is 200 lbs. of withered leaf at each charge.

To clean this pattern of machine, the top plate or table can be swung out of the jacket or case which surrounds it by means of a davit.

The larger-sized, or 32-inch, machine is fitted with pulleys

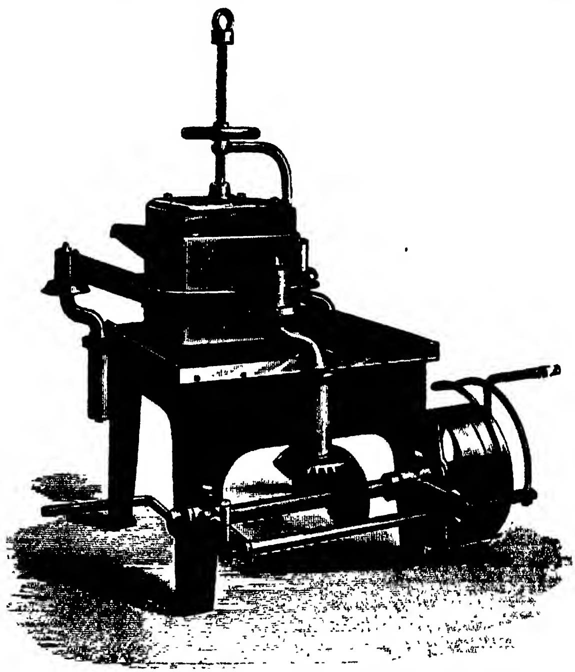


FIG. 52.—Small Square-pattern Single-acting Tea Leaf Rolling Machine, arranged for Hand or Power Driving.

24 inches in diameter by 5 inches on face, and the speed at which it should be driven is one of about 140 revolutions per minute. The smaller-sized, or 24-inch, machine has pulleys 18 inches in diameter by 4½ inches on face, and should be run at a speed of about 166 revolutions per minute. The power required for driving will be 4 h.-p. in the first and 3 h.-p. in the second case.

The circular-pattern machine, shown in Fig. 51, is constructed in practically the same manner as the square-pattern one, and the principle upon which it works is identical. It is capable of containing a charge of 300 lbs. of withered leaf, and is worked at the same speed and requires the same power to drive as the larger sized square-pattern machine.

Another of these machines is also of the circular pattern, but single acting—that is to say, so constructed that the bottom table remains stationary. Consequently this machine is one which especially lends itself to the provision of a granite lower table, which latter type of table has been found to be practically everlasting.

In other respects, however, the construction of the machine does not differ materially from the preceding, the main difference being that the bevel or mitre gear wheels are in this case arranged inside the hollow part of the front standard, which, being maintained closed during the working of the machine, renders any accident, through the attendant or others coming in contact with this gearing, an impossibility, and likewise effectively protects it against dust and dirt, as is also the case in Fig. 50.

The capacity of this machine is also 300 lbs. of withered leaf at each charge, but it requires considerably less power to drive, from 2½ to 3 h.-p. being sufficient. It should be run at a speed of about 120 revolutions per minute.

The little single-acting square-pattern machine shown in Fig. 52 is designed for use on small estates, or as an auxiliary in factories on large plantations.

As will be seen from the illustration, it is so arranged that it can be worked either by hand or power. The top plate or table has a traversing motion imparted to it by three cranks, and the rolling surfaces are either of wood or, what is preferable, of wood faced with brass. The descent of the cap exerts the requisite pressure upon the leaf that is being rolled, the hand wheel and screw being intended for lifting purposes only.

This machine is capable of receiving a charge of about half-a-maund or 40 lbs. of withered leaf, and should be driven at a speed of some 60 revolutions per minute.

Two other of these tea leaf rolling machines consist, briefly, the first, of two opposed plates actuated by crank shafts, the uppermost of these plates being contained in a jacket, and

connected with a screw and hand wheel for the purpose of enabling the plate to be raised or lifted, so as to permit of the introduction of the tea leaf through a lateral hopper, and also to allow the pressure on the leaf during the rolling operation to be suitably adjusted. The lower, which is also the larger plate, is dished or hollowed out at the centre, and is provided with a discharging door.

The driving shaft is carried by a suitable bracket, and is arranged to actuate, through a set of bevel or mitre gearing, another shaft having two cranks, the first of which has a bearing in the framework of the jacket supporting the upper plate, and the latter of which is mounted and works in bearings attached to the lower plate. Two other similar shafts, moreover, carrying double cranks, are suitably mounted in pillars situated at the other end of the machine, and are in like manner connected with the two plates to which they act as guides.

In order to admit of the driving shaft being placed in any desired position, the bracket in which it is supported is so arranged as to be capable of rotation, and of being fixed in any convenient position by means of dovetail-headed bolts engaging in a groove in the frame of the machine.

The second machine comprises a revolving barrel, preferably composed of teak wood, and having a polygonal, grooved, fluted, or other uneven inner surface, a correspondingly externally-grooved, fluted, or roughened roller being arranged to revolve within it.

The cylinder is secured at one end to a sleeve provided on the frame of the machine, through which a shaft secured to the inner roller passes, and is supported at the other end on rollers, the inner roller shaft being supported in suitable bearings in the frame. These rollers are arranged to be rotated through toothed gearing simultaneously in opposite directions, one of them at a higher speed than the others.

The leaf to be rolled can be fed from a trough or hopper on the top of the machine through a hole in the stationary side plate into the rotating barrel, and it will be rolled or curled whilst passing through the space or clearance between it and the inner roller, its passage through the machine being facilitated by internal projections on the barrel.

The discharge can be effected either by lowering the non-rotating plate at the other, or discharge, end of the machine, or through a door provided in the plate. The speed with which different varieties of leaf would pass through the machine can be regulated by mounting the frame of the latter at the feed end upon an axis, and providing vertical screw adjustment at the other, or discharge, end.

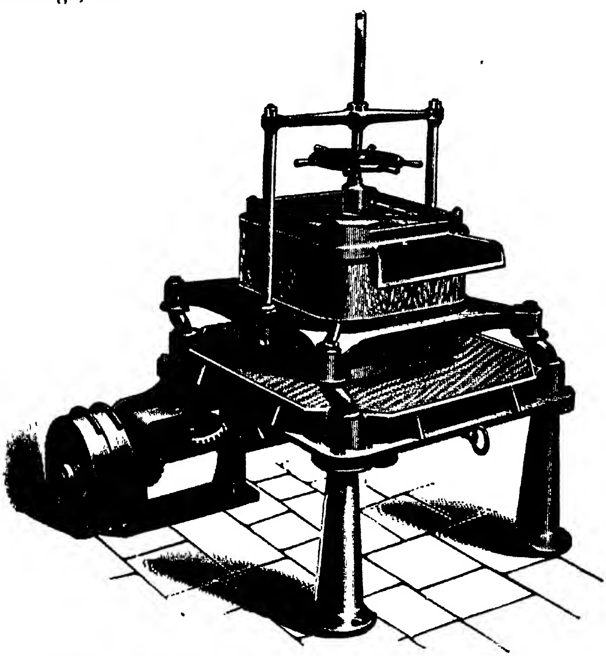


FIG. 53.—Open or Closed Top Square-pattern Single-acting Tea Leaf Rolling Machine.

In Fig. 53 is illustrated Begg's single-acting square-pattern machine, which is made by the Blaxton Engineering Co., Limited, London. This tea roller is adapted for use either as a closed machine, as shown, pressure being in that case applied as lightly or as heavily as may be found requisite by means of a simple mechanical arrangement; or, if desired, it may be worked as an open-top machine.

It is claimed that this machine enables the twist or curl in the leaf to be obtained to a great degree of nicety without entailing balling or breakage of the leaf to any appreciable amount, and, moreover, that the leaf is kept cool during the rolling operation.

The discharge of the rolled leaf can be effected through a trap door in the lower stationary table, the opening or closing of which

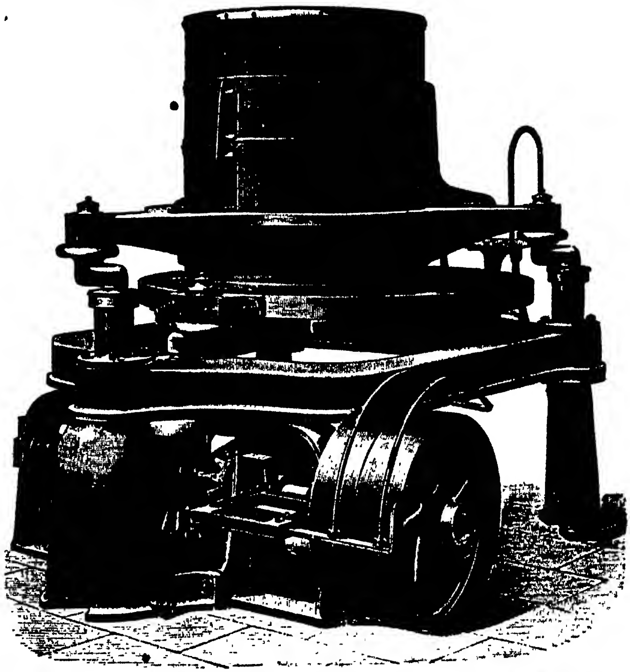


FIG. 54.—Large Size Circular-pattern Double-acting Open-top Tea Leaf Rolling Machine, with oppositely moving Tables or Rubbing Surfaces.

can be operated by the handle shown on the right hand side of the illustration.

The machine will take a charge of 300 lbs. of withered leaf at a time, and being of the single-acting type, only requires a comparatively small amount of driving power, 1½ h.-p. being sufficient when fully charged.

As will be seen from the illustration, the characteristic feature of this machine is an extreme simplicity of construction.

A class of tea leaf rolling machine now held in considerable esteem, is that in which the top of the leaf receptacle or cylinder is left open; and two patterns of tea rollers constructed on this plan are shown in Figs. 54 to 56.

The first of these machines, or that illustrated in Fig. 54, is one designed and built by Ransomes, Sims & Jefferies, Limited, Ipswich, by whom this type of machine was first introduced.

The main frame of the machine is supported upon three pedestals, and is of peculiarly massive construction, so much so, indeed, as to require but a very slight attachment to the floor of the machine room in order to insure its fixity.

The machine is one of large size, and of the double-acting type. The cranks for operating the upper and lower table are formed on separate crank shafts, driven in opposite directions through a suitable train of bevel and toothed gearing, thereby imparting a very peculiar and, it is claimed, most effective movement to the upper and lower tables.

A special feature of this machine is the rolling cylinder, which is secured to the upper table, and is of large capacity. It is constructed of brass, and is fitted with vertical ribs to promote a thorough circulation of the rolled leaf. The effect of these ribs is to maintain the leaf in constant movement and to render the action of the machine very rapid, the production of rolled, well-twisted or curled leaf being large, and, what is also a matter of some importance, kept in a perfectly cool state.

Access to the upper rolling box or cylinder, for charging the apparatus with the withered leaf, can be readily had by means of a footplate with steps and handrail, which are fitted to the rear of the roller, and can be seen on the right hand side of the illustration.

A door, fitted with a spring catch and capable of being readily opened or closed from the outside of the machine, admits of the withdrawal of the rolled leaf through an aperture formed in the lower table.

The countershaft of the machine is fitted with a pair of fast-and-loose pulleys, 24 inches in diameter by 6½ inches on the face, and a suitable striking gear is also provided. This countershaft should be speeded to run at 140 revolutions per minute.

The machine is capable of holding a charge of eight maunds, or 640 lbs., of withered tea leaf, and the time occupied in rolling varies from twenty to thirty minutes, in accordance with the condition of the leaf. About 4 h.-p. is required for driving.

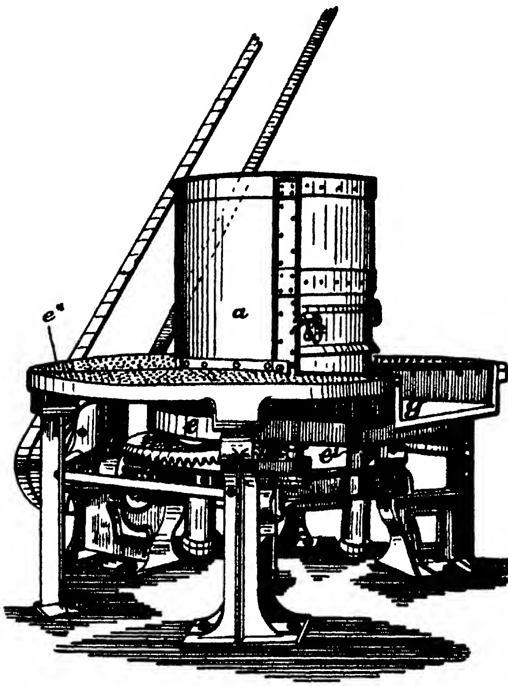


FIG. 55.—Open-top Stationary Leaf Receptacle Rotary Table Pattern of Tea Leaf Rolling Machine (perspective view showing Receptacle Closed).

It is claimed by the makers of this machine that the pear-shaped movement produced by the peculiar motion of the upper and lower rolling plates gives a peculiarly effective twist to the leaf.

Another pattern of open-top tea leaf rolling machine lately brought out by S. C. Davidson[1] is shown in Figs. 55 and 56. This machine has the advantage of possessing very few moving

[1] Built by Davidson & Co., Ld., Belfast.

parts, as compared with many of the other leaf-rolling machines in use, the result being a saving in the power required for driving, in comparison to that necessary for those of more complicated construction, none being absorbed in imparting motion to the leaf receptacle or cylinder and to the charge of leaf contained in it.

The stationary leaf receptacle or cylinder *a*, is left completely open at the top, and the rolling action of the leaf is effected by means of parts *b*, which the makers have termed ploughs, in combination with a conical-shaped projection *c*, in the centre of a cavity or well *d*, in the rotary rolling table *e*.

All the parts of the machine which come in contact with the leaf—that is to say, the leaf receptacle or cylinder, the ploughs, the rolling table, and the discharge tray—are made of brass.

A suitable side door *f*, shown closed in Fig. 55 and open in Fig. 56, to allow the internal construction of the machine to be seen, is provided in the stationary leaf receptacle or cylinder, and in front of this discharge door is situated the discharge tray or shelf *g*, in the fixed table or platform *e**. This arrangement allows of the driving gear and supporting cranks being placed further under the centre of the rolling table than is possible when the discharge takes place through a trap door in the rolling table, as is usual in the moving receptacle or table type of machines.

An arrangement is also provided by means of which any leaf and juice which may escape through the clearance space between the lower edge of the leaf receptacle, and the upper surface of the rolling table will be automatically swept round to a delivery spout c^1, on the fixed table *e**. The table *e* is rotated through suitable gearing.

The machine operates in a very simple manner. The discharge door *f*, in the side of the stationary leaf receptacle or cylinder being first closed and bolted, the machine is set in motion, and the charge of withered leaf is gradually but quickly emptied into the top of the receptacle or cylinder *a*, in which the combined action of the rolling table *e*, and of the ploughs *b*, imparts a strong internal pressure to the leaf, and forces the central portion of the mass of leaf to move in an upward direction and to return in a downward direction all round the sides, thus giving to the leaf an equal and well-twisted rolling, with the production of a very small amount of broken leaf.

During the rolling operation the leaf is also kept completely aerated, and is cooled throughout its entire mass.

The leaf and juice escaping through the clearance between the rolling table and the leaf receptacle being collected as they escape through the delivery spout e^1, already mentioned, can be periodically returned into the top of the receptacle.

To discharge the rolled leaf, the door *f* in the side of the leaf

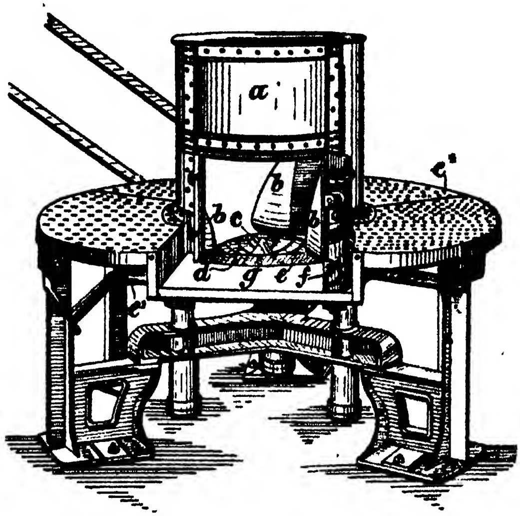


FIG. 56.—Open-top Stationary Leaf Receptacle Rotary Table Pattern of Tea Leaf Rolling Machine (perspective view showing Leaf Receptacle Open).

receptacle or cylinder is unbolted and opened whilst the machine is still running, when the motion of the rolling table *e* will automatically eject the rolled leaf on to the discharge shelf or tray *g*, in front, the small quantity remaining in the well *d* of the rolling table *e* being cleared out after the machine has been brought to a standstill.

The machine is capable of receiving a charge of 350 lbs. of withered leaf, and requires only 2 h.-p. to drive it. The average time required to roll a charge will be about half an hour. The

approximate over-all dimensions of the machine are—length 8 ft. 7 in., width 7 ft. 2 in., and height 5 ft. 6 in.

Amongst other patterns of machines for rolling and curling the tea-leaf that have been proposed, mention may be made of the following:—

The tea-leaf rolling machine designed by A. H. B. Sharpe, working on the principle in which the rolling or curling is effected between two plates moving in opposite directions, and which comprises a method of imparting continuous circular motion to the plates by means of eccentrics fixed to vertical shafts. Rotary motion is transmitted from the driving shaft by means of bevel and belt gearing, the lower plate being fixed in a frame having semicircular straps for inclosing the eccentrics. The uppermost of these plates is circular, and is inclosed in a casing surrounded by a frame having extensions provided with straps for the upper eccentrics, and also with a hopper and pillars carrying a platform provided with bearings for the shaft or spindle of a hand wheel operating a bevel wheel, which latter acts as a nut on a vertical screw-threaded shaft, thus admitting of any desired pressure being brought to bear upon the upper plate. The tea when sufficiently rolled can be discharged through a door in the lower plate in the usual manner.

In a machine operating on the same principle devised by H. Thompson, the lower of the two rolling surfaces or tables has underneath it a central cylinder, in which is arranged to work vertically a plug or stopple. The upper table, which is operated by the upper crank on a double crank shaft, driven through bevel wheels by the main shaft, is also supported upon cranks, and consequently has a circular motion imparted to it. The under table is operated by the lower crank upon the double crank shaft, and is supported also by slide blocks fixed to it, and placed in guides upon a frame pivoted or mounted on a central pivot pin, thus giving to it a pear-shaped motion.

The plug or stopple in the central cylinder of the lower table is provided with a suitable door, which can be readily raised or lowered by means of cords passing over pulleys, which latter can be operated when desired by a shaft carrying a worm wheel driven by a worm on the shaft of a hand wheel.

The use of the stopple is, after the tea has been fed into the

space from a hopper on the upper table, to subject the leaf to pressure by moving it up or raising it.

J. Richardson's tea-leaf rolling machine is characterised by the employment of glass in the construction of the tables or rolling surfaces. With this object, a plate or sheet of glass is let into the upper surface of the lower table, and is cut out in the centre so as to form a well, the hard wood walls or sides of which are arranged to overlap the edges of the glass sheet; or they are formed of glass in one piece with the sheet, or of separate sheets of glass moulded to fit into position.

The rolling is effected by a circular movement of the upper frame, within which is mounted a hollow plunger for exerting pressure on the leaf.

Fig. 57 illustrates a tea-leaf rolling machine designed by Kinmond and Richardson.

The cylindrical hopper or leaf receptacle *a* is lined with wood, and is designed to receive the tea-leaf to be operated upon through an opening *b* situated at one side thereof. Within this circular or cylindrical hopper or casing is arranged an upper table *c*, shown in dotted lines in the drawing, which table is free to move vertically, and can be raised or lowered at will by means of a screw *d*.

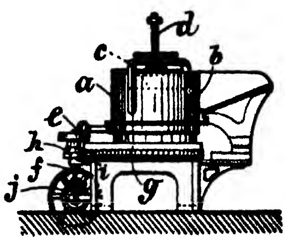


FIG. 57.—Circular pattern double-acting Tea Leaf Rolling Machine, with oppositely moving rubbing surfaces (Side elevation).

The hopper or casing *a* and upper table *c* receive motion at one side from a crank *e*, mounted upon a vertical crank shaft *f*, a suitable pin moving in a slot being provided at the other side of the table for guiding purposes. The lower table or rubbing surface *g*, is caused to revolve upon its centres in a contrary direction to the hopper *a*, and upper table *c*, by an eccentric *h*, mounted on the vertical crank shaft *f*, and by ratchet gear *i*. Rotary motion is communicated from the driving shaft to the vertical crank shaft *f* by means of bevel or mitre wheels *j*.

A somewhat curious description of tea-leaf rolling machine devised by J. P. Brougham consists of a board or table fixed in

an inclined position, over, and parallel to, which is arranged a reciprocating board or table, either one or the other of these boards or tables being cushioned with some elastic material. A sheet of indiarubber, leather, or the like is attached to the higher end of the lower or fixed table, and is carried down loosely between the two tables to near the bottom of them, where it is doubled back in a U-form, and its other end attached to the higher end of the upper table.

The tea-leaf to be treated is placed in the U-shaped fold of the above-mentioned material, and is rolled by the reciprocating motion of the upper table, which movement is effected by means of a connecting rod from a crank on a driving shaft. Boards or guards fixed to the lower table prevent the leaves from falling out of the U-shaped fold of cloth.

The principle upon which this machine works is, it will be seen, similar to that of a well-known device for rolling cigarettes.

In a machine previously designed by the same gentleman, a cylinder of sheet-iron or wood, mounted horizontally through hollow gudgeons so as to be free to rotate in suitable bearings, and which could be actuated by suitable spur or toothed gearing, is employed.

In these hollow gudgeons is mounted a shaft or spindle which passes through the cylinder, and has rotatably and adjustably supported, by means of slots at the ends of lever arms fixed thereon, a roller of nearly the same length as the cylinder. A handle or lever on one end of the above-mentioned central shaft, and a catch, admits of these arms or levers and roller being adjusted to any desired angle within the cylinder, in accordance with the amount of pressure which it may be found desirable to exert upon the tea-leaf, which latter, it will be seen, will be forced to pass between the roller and the inner wall of the cylinder during its revolution, the roller being free to rise to a certain extent in the supporting slots so as to allow of the passage under it of rolls of leaves of varying thickness.

A suitable door is provided in the cylinder to admit of the insertion and removal of the tea-leaf.

A. C. G. Thompson proposes to roll tea-leaf by means of a machine comprising a globe, preferably hollow, fixed on a horizontal axis, supported in bearings in a fork piece, and carrying a bevel or

mitre wheel gearing or meshing with another bevel or mitre wheel, fixed to the frame of the machine. This fork is provided with a vertical axis rotatably mounted in bearings in the framework, and carrying a spur or toothed wheel gearing with a pinion on the driving shaft. Beneath the above-mentioned globe is provided a saucer-shaped or concave vessel mounted on a spindle, carrying a spur or toothed wheel, driven through an intermediate wheel by a pinion on the driving shaft. When this latter shaft is rotated, the concave or saucer-shaped vessel will revolve in an opposite direction, and the globe be caused to turn round both axes, the former being pressed in an upward direction by springs or by a weighted lever. The rolled leaves can be withdrawn either through an opening in the saucer-shaped or concave vessel, or by lowering the latter.

Some years ago a triple action tea roller was invented by Mr. Brown, and introduced by the Columbo Commercial Company, London. The rolling tables of this machine are carried on a cast-iron frame, which admits of the passage of a trolley underneath the lower table, to receive the rolled leaf as discharged. The rolling tables are carried on sliding surfaces secured to the frame, and the requisite motion is imparted to them through two vertical crank shafts. The lower rolling table is circular, dished from its outer edge to the centre, and covered on its entire rolling surface with battens, a central circular door being provided for the discharge of the rolled leaf, and for admitting of access being had to the interior of the box for cleansing purposes. This lower table has a rotary motion imparted to it, and the upper rolling surface, which is also circular in form, has both a gyratory motion, and is likewise caused to rotate on its own axis, this combination of motions being claimed to prevent the leaf from becoming stagnant in the upper portion of the box when heavy pressure is brought to bear upon it, and also to greatly facilitate the rapid manipulation of the leaf.

The leaf receptacle or box is made of brass, and is so mounted as to be free of both the upper and lower rolling tables, and so as to provide perfect ventilation, and thus to prevent heating of the leaf. The pressure put upon the leaf can be regulated by a lever and a counterbalance weight, or the lever can be fixed by a pin, so as to hold the upper rolling table firmly down on the leaf.

CHAPTER VII.

FERMENTING PROCESS.

Machines for Breaking-up or Separating the Balls or Lumps of Leaf formed during the Rolling Process—Machines for Oxidizing or Cooling the Leaf—Machines for Effecting or Accelerating the Fermentation of the Leaf.

DURING the operation of rolling the leaf, a certain number of balls or tangled compacted masses or lumps of leaf usually become formed, and, as has been before mentioned in a previous chapter, these must be disentangled or picked to pieces, otherwise the fermentation would be of an uneven character. This operation, which was formerly done by hand labour, is now effected in all modernly-equipped tea factories by means of machinery.

MACHINES FOR BREAKING-UP OR SEPARATING THE BALLS OR LUMPS OF ROLLED LEAF.

These machines are all mainly composed of a revolving wire screen of some suitable description, or of an arrangement of rotating arms or beaters, or again, in some instances, of a combination of both, and the three patterns which are illustrated in Figs. 58 to 61 will be sufficient to make the construction of the whole of this class of machine clear.

The first of these machines, or that shown in Fig. 58, which is one designed by W. and J. Jackson, and manufactured by Marshall, Sons & Co., Limited, Gainsborough, consists, as will be seen by a glance at the illustration, of a revolving inclined screen, into the circular mouth of which the rolled leaf or mal is fed, the smaller leaf escaping through the half-inch mesh wire of which the screen is composed, and the interwoven or tangled lumps or balls being dropped on to the pronged beater located centrally in the screen,

and to which a high speed is imparted. The effect of this is both to completely break up and disentangle these balls or lumps, and also to ventilate or cool down the leaf thoroughly.

The driving pulleys, which are 18 inches in diameter by 2½ inches on face, should be run at a speed of 80 revolutions per minute, and 300 lbs. of rolled leaf or mal can be passed through the machine in from three to five minutes, according to the amount of breaking-up or separating and cooling that may be required.

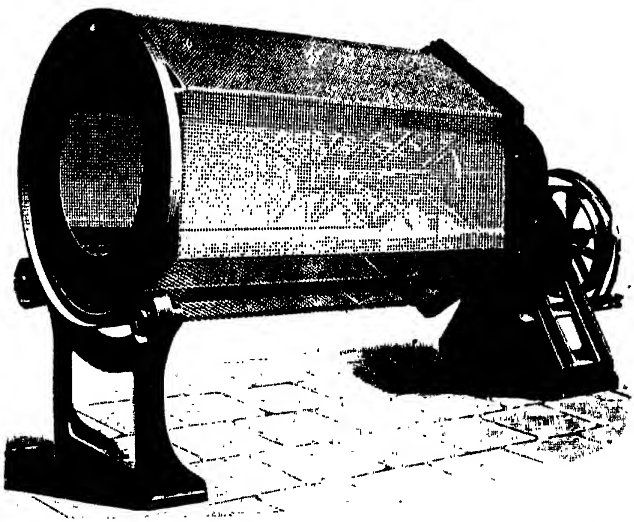


FIG. 58.—Revolving Screen Machine for Breaking Up or Separating Balls or Lumps of Rolled Leaf.

A roll or ball breaking machine designed by C. S. Davidson[1] is illustrated in Fig. 59.

This machine, which is also intended to act in the capacity of a sorter, comprises a cylinder fitted with strong wire web of two sizes of mesh. The cylinder can be rotated by gearing—a description of which will be found later on, with reference to the sorting machine of the same gentleman—and it is fitted with a screw

[1] Manufactured by Davidson & Co., Ltd., Belfast.

adjustment at its lower end, so that the angle at which it works can be raised or depressed, and thus a quick or slow passage through it imparted to the leaf.

The driving power required by this machine is very slight, and it could, if desired, be fitted with hand-power gear and be easily worked by manual labour.

The method of working the machine consists in emptying the leaf as it comes from the rolling machine into the leaf-receiving

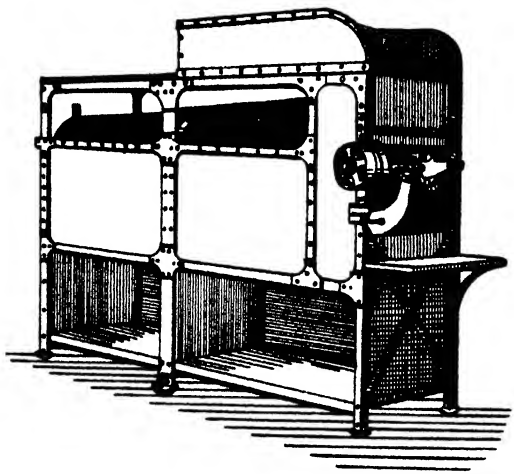
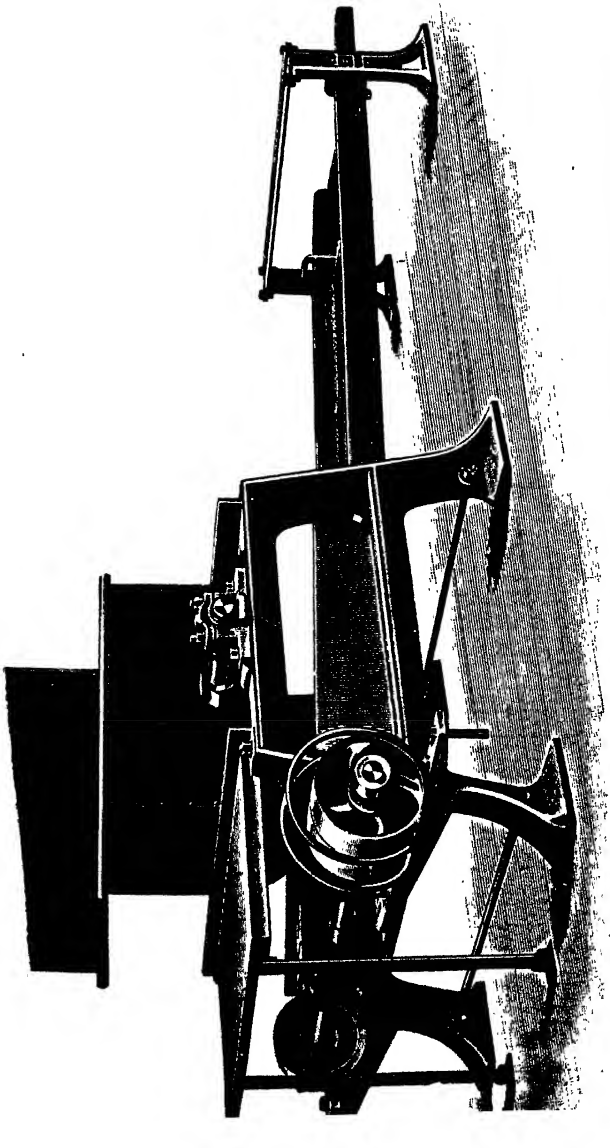


FIG. 59.—Roll or Ball-breaking or Separating and Tea Leaf Sorting Machine.

hopper or bin shown on the top of the machine, the operator or attendant, who stands on the small platform shown at the front end of the latter, drawing the leaf forward by means of a hand rake or drag into a hopper shoot at the front edge of the bin, from which it is delivered directly into the upper end of the ball-breaking and sorting cylinder. In this latter a separation is effected of the fully rolled and fine from the medium-sized leaf, the coarse and insufficiently rolled leaf being ejected at the lower end of the cylinder, when it may, if desired, be further rolled. Thus each of the three classes can be fermented separately, thereby enabling the best



IG. 60.—Combined Rolled Tea Leaf Separator or Ball-breaking Machine, Ærator, and Sifter (perspective view looking from feed end)

results to be obtained, as the finest qualities, which invariably undergo the most rapid fermentation, when separated in the manner above described, can be dried off as soon as they have obtained a sufficiently advanced stage of fermentation, without having to keep them waiting until such time as the coarse leaf, which always requires a longer period in which to undergo fermentation, is ready, as obviously must be the case when the three qualities are all fermented together in bulk.

The approximate over-all dimensions of this machine are—length 10 ft. 9 in., width 3 ft. 8 in., and height 6 ft. 6 in.

Figs. 60 and 61 are two perspective views, looking from the feed end and the discharge end respectively, and illustrating a combined rolled tea-leaf separator or ball breaking machine, an aerator, and a sifter, which is an improvement upon the original pattern of machine, made by Richard Moreland & Son, Limited, London, designed by Nathan Sharpe, this machine being likewise manufactured by the above firm.

The ball-breaking apparatus consists essentially of a feed hopper communicating with a box or casing through a suitable feed aperture, in which box or casing gun-metal arms or beaters are arranged to rotate, an air propeller or fan, working in conjunction with the beaters, forcing a current of air through the hopper box or casing.

Beneath this latter is the upper or feed end of a sieve or sifter, fitted with half-inch meshing, the discharge end of which is so arranged as to be adjustable vertically by means of sliding blocks and screws, thus admitting of its incline being altered at any moment.

The operation of the apparatus is exceedingly simple. The attendant, resting his basket of rolled leaf or mal on the platform, pushes a quantity of the rolled leaf along the hopper to the feed aperture, through which it falls, the lumps or balls of rolled leaf becoming disentangled and broken up by the gun-metal beaters or arms revolving rapidly within, and a current of air being meanwhile blown through the hopper box or casing by the air propeller or fan revolving with the beaters or arms, which current of air will very considerably reduce the temperature of the rolled leaves.

The leaf eventually falls on to the sifter below, the finer quality passing through the meshes, and the coarser portion being discharged at the delivery end of the apparatus.

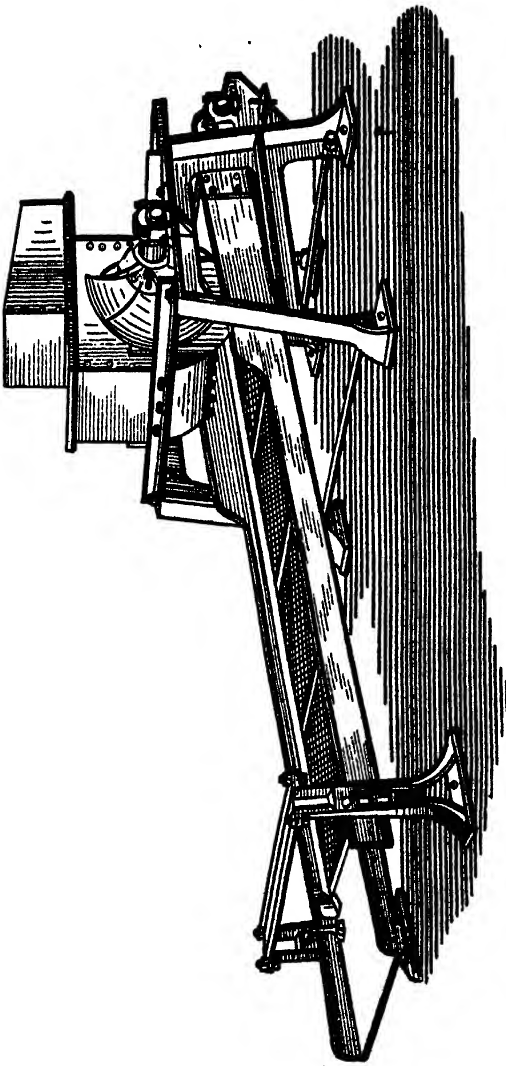


Fig. 61.—Combined Rolled Tea Leaf Separator or Ball-breaking Machine, Ærator, and Sifter (perspective view looking from discharge end)

The driving pulleys are ten inches in diameter by three inches on face, and the speed should be about 250 revolutions per minute.

The capacity of this machine is considerable, a single one being usually found to be sufficient to serve six rolling machines, and the results attained being also said to be highly satisfactory, a certain grading of the leaf being assured, and great coolness obtained; and, furthermore, the disentangled, cooled, and sifted leaves, after quitting the machine, being in the best possible condition for undergoing the oxidizing or the fermenting process.

Machines for Cooling or Oxidizing the Leaf.

It is found to be, as has been before mentioned, of considerable advantage to chill, cool, or oxidize the rolled leaf after it comes from the rolling machine, and likewise to evaporate a certain proportion of the moisture contained in it before subjecting it to the process of fermentation, both of which useful offices can be effected in a satisfactory manner by means of the machine devised by S. C. Davidson, which is illustrated in Figs. 62 to 66.

Briefly, this machine consists of a horizontal chamber divided up into a number of separate compartments, each of which compartments is fitted on the top with a perforated or wire mesh tray, upon which the rolled leaf is spread. An air duct, leading to an exhaust fan, is arranged to communicate with each of these compartments through a valve port, which can be opened or closed so as to put the compartment in communication with or cut it off from the exhaust fan, by means of a connecting rod, the handle or end of which projects through the front of the horizontal chamber to within easy reach of the operator.

When the machine is fixed in position, the nozzle of the fan should be connected through a suitable pipe with the exterior of the machine room, otherwise the air in the latter would rapidly become too damp to enable it to absorb the required moisture from the leaf.

The operation of the machine is as follows:—Upon a trayful of leaf being placed upon the top of any one of the compartments, and the valve port affording communication between that compartment and the air duct being opened by drawing forward the corresponding valve handle, the exhaust fan will act to suck the

air away from below that tray, and a strong downward current from the air of the room in which the machine is working will be drawn down through the leaf, thus producing an evaporation of moisture which will chill the leaf in a few minutes, reducing it from whatever may have been its temperature at the time of placing it upon the tray down to about 60° or 70° Fahr.

The air duct must be occasionally shut off during the progress of the operation, and the layer of leaf, which is one of some thickness, turned. When the operation is completed, the communication valves between the compartments and the air duct must be likewise closed.

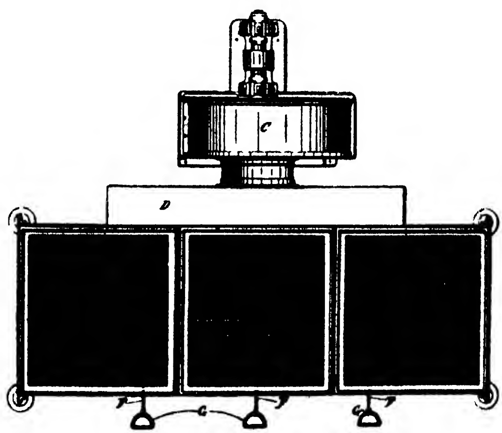


FIG. 62.—Three-Tray Down-Draught Tea Leaf Cooling or Oxidizing Machine (plan).

The trays of the oxidizer are each capable of accommodating about 70 lbs. of rolled leaf, so that the most usual charge of a large-sized rolling machine could be easily dealt with at one time by means of a five-tray oxidizer, and the chilling or oxidizing of the leaf will be completed by the time another charge of leaf has been rolled.

Amongst the advantages derived from the exposure of the leaf to this chilling or cooling and oxidizing action are the following:

When the leaf has been subjected to this operation, the

subsequent fermentation can be carried out at a low temperature. Besides, if the leaf be taken almost direet from the rolling machine and placed upon the trays of the oxidizer, it is rendered more sticky and gummy by the passage of the air through it, which is said to have the effect of causing the leaf to acquire a

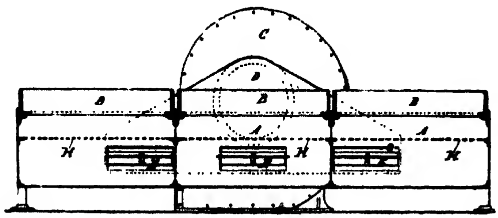


FIG. 63.—Three-Tray Down-Draught Tea Leaf Cooling or Oxidizing Machine (longitudinal section).

very agreeable aroma during any subsequent fermentation to which it may be subjected, the liquor of the finished tea being likewise brisker than would be the case were the process of fermentation carried out without this preliminary chilling or cooling and deprivation of a portion of its moisture. The leaf also, owing to the sticky or gummy characteristics which it assumes, facilitates a tighter twist being obtained during the second rolling operation.

By this simultaneous cooling and partial drying of the leaf, moreover, it will not only undergo at a sufficiently cool temperature the process of fermentation, but it will also become at the same time sufficiently dry to allow of its being then subjected to complete drying by means of strong heat, without this heat causing that deterioration of the quality of the product to which it is liable, when subjected to the action of strong heat, in the very moist condition in which the ordinary fermentation process leaves it.

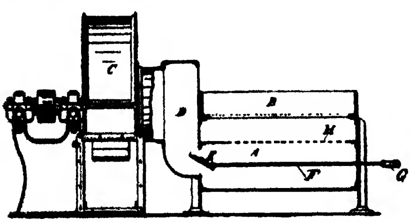


FIG. 64.—Three-Tray Down-Draught Tea Leaf Cooling or Oxidizing Machine (transverse section).

Figs. 62 to 64 illustrate a small three-tray cooling or oxidizing machine, the construction being the same as that of larger ones having five or more trays.

The apparatus consists essentially of a box or chamber A having an open top into which slides are fitted to carry sieves or perforated trays B, on which a layer of rolled tea-leaf of suitable depth can be spread. The trays are made of wire netting; or coarse cloth or other material, through which the air will easily pass, may be used. The lower part of the box or chamber A is connected to a fan C, by which a strong current of air can be drawn down through the material on the trays B, into the common air duct D, and finally exhausted into the atmosphere.

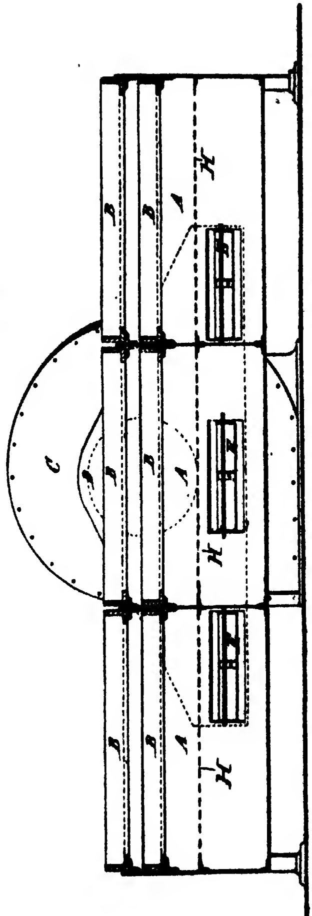


Fig. 65.—Six-Tray Down-Draught Tea Leaf Cooling or Oxidizing Machine (longitudinal section).

E are valves or dampers for cutting-off, and admitting, or for regulating or controlling the air current or blast from each tray or set of trays (Fig. 64) with respect to the common air duct or passage D. These valves or dampers E can be operated by rods F, the handles G of which are so placed as to be within easy reach of the operator. H are perforated plates, one of which is arranged below each tray so as to equalise the current of air passing through the material on the same.

To employ the apparatus for simultaneously cooling and partially drying the tea-leaf, the latter, immediately or soon after it comes out of the rolling machine, at which time its temperature will have become increased to about 10 or 15 degrees above the ordinary atmospheric temperature at which it was before the rolling operation, is spread in layers a few inches thick on the trays. A current of more or less desiccated air at or slightly above the ordinary atmospheric temperature is then drawn through it, until a considerable portion of the moisture of the leaf has been carried off. This evaporation will cause a reduction in the temperature of the leaf to very considerably below that of the atmosphere, and this effect will be maintained so long as any evaporation is taking place.

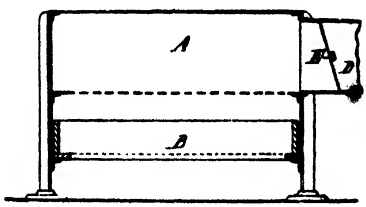


FIG. 66.—Up-draught Inverted Tray Pattern Tea Leaf Cooling or Oxidizing Machine (transverse section).

As soon as the surfaces of the leaf are found to be drying, it may be again subjected to the rolling process, after which it will be found advisable to replace it in the trays of the oxidizing machine and to cool it down. In fact, the operation can be repeated as many times as may be deemed desirable, and when the juices are found to be getting sticky or gummy the leaf can with advantage be completely dried in the usual way in the drying machines.

In cases where the atmosphere is very damp, the air, before being drawn or forced through the material on the trays, may be artificially dried by raising its temperature some 10 or 15 degrees above that at which it previously stood, which may be conveniently effected by either drawing it over heated pipes or by employing an air-heating stove.

In Fig. 65 is shown a six-tray oxidizing machine, in which the trays are superimposed or arranged in columns, two trays being placed in each column. The reference letters on this illustration refer to the same parts as those on Figs. 62, 63 and 64, consequently the same description will apply in this case.

Fig. 66 shows an arrangement in which the trays B are

inverted, the tray slide being below and the air exhausted from above them, so that the current of air will be caused to pass in an upward direction through the tea-leaf.

The approximate over-all dimensions of a five-tray cooling, chilling, or oxidizing machine, which is the size most generally made, are—length 17 ft. 6 in., width 8ft., and height 4 ft. 6 in.

Apparatus for Effecting or Accelerating the Fermentation of the Leaf.

The leaf is in some cases spread upon tables, or on tiers, or ledged shelves, in layers of from 3 to 4½ inches in thickness, in accordance with the temperature of the day, and other conditions, every effort being made to keep the leaf cool. This latter purpose can be very efficiently performed by the provision of a suitable refrigerating apparatus, such as that described and illustrated on pages 322 to 329, the fermenting room being cooled by a suitable system of pipes.

The great secret of success is to be able to check the incipient fermentation at exactly the right stage, the quality being inevitably injured by too little or too much fermentation.

The time occupied by the operation varies, as a rule, from three and a half to five hours, or even to six hours towards the close of the season, and at high elevations.

According to Mr. Christison, the surest sign of a favourable result is when a bright salmon colour resembling that of a new penny is obtained in the mass.

An apparatus was designed a short time back by N. W. H. Sharpe for accelerating the fermentation of the leaf, which comprises an arrangement of fans for blowing moistened air over the leaves whilst they are spread upon trays supported upon a suitable framework.

This framework is surrounded by curtains, which are mounted by means of rings upon rods, and are kept constantly moistened by water which flows down them from a perforated pipe connected with a reservoir.

At the extremities of the apparatus are located air blasts or exhaust fans for causing air to pass through the curtains, which

at the ends of the framework consist of an open material, such as gunny cloth.

This apparatus is also said to be suitable for withering, if the water supply be omitted and hot air be delivered through suitable openings provided in stout curtains.

CHAPTER VIII.

MACHINES FOR THE AUTOMATIC DRYING OR FIRING OF THE LEAF.

Down-draught Automatic Drying Machines—Up-draught Automatic Drying Machines — Steam-Heated Automatic Drying Machines — Steam-Heated Automatic Machines for Drying or Firing the Tea *in Vacuo*.

AFTER having been subjected to the fermentation process, the leaf is next re-rolled, and if desired might, as has been already mentioned, prior to passing it into the drying or firing machines, be again, with advantage, put through the leaf-chilling and oxidizing machine illustrated in Figs. 62 to 66, by the action of which the colour of the leaf is said to become instantaneously fixed, and further fermentation to be temporarily checked owing to the chilling or cooling it will thus receive.

The drying or firing machines may be divided into two main classes, viz.: Firstly, those which act automatically—that is to say, machines of that kind or class wherein the leaf is fed in at one end, and when the drying operation is completed, so far at least as that particular machine is capable of effecting it, is delivered out or discharged at the other end—the duration of the operation and, to a certain extent, the degree of heat applied being the only points under the control of the attendant; and, secondly, non-automatic machines in which the leaf is completely under the control of the attendant during the whole of the drying or firing operation.

Both these classes of machines may again be subdivided into machines wherein an artificial down draught and those in which an artificial up draught is employed—that is to say, in which the current of air is either passed or drawn in a downward or in an upward direction through the leaf; and the second class of

machines, further, into those in which an artificial, and those in which a natural draught is used.

Machines of the first of these main classes are generally employed for the primary stages of the drying or firing of the leaf; and those of the second for the final stages of this process, and also for the re-firing of the finished tea before packing.

Automatic Down-Draught Tea Drying Machines.

Dealing first with drying or firing machines of the automatic down-draught pattern.

The best-known makes of this type of drier will be found illustrated in Figs. 67 to 90. The machines shown in Figs. 67 to 72, which are the invention of S. C. Davidson, belong to that class of apparatus in which the tea to be dried is exposed on perforated plates or trays to a current of heated air passed through the plates or trays, which are moved forward and backward in a drying chamber or box between and by means of endless travelling bands or chains passing round two or more returning wheels, and the trays or plates being so adjusted between these bands that the edges of the trays, in one form of the apparatus, will overlap one another, and in another form of machine will touch or overlap at the edges.

A feature of this machine is the utilisation as a drying surface of each horizontal stretch of an endless web, which consists of flat perforated plates or woven-wire trays which have their edges overlapping, or of trough-shaped trays the edges of which either touch or overlap one another, these flat plates or trays or trough-shaped swinging trays being carried on pivots between endless bands or chains passing round two or more returning wheels as a continuous web, and the material which is being dried on the trays or troughs being automatically delivered down from stretch to stretch as the web moves forward, by the tilting or overturning of the trays consecutively, as they reach or approach the end of each stretch, in such a way that the tea-leaf will get turned and re-spread at each transfer, and fresh surfaces of it will in this manner become exposed to the action of the current of air which is being drawn through it, the drying being thus more evenly and rapidly effected than if the tea were not turned or tossed during its passage through the drying chamber.

The employment of the under or returning horizontal stretch of endless bands or trays of a drying apparatus as drying surfaces, in combination with the dropping of the material from the upper to the lower stretch of trays, in other machines of this type, is usually effected by means of endless conveying or carrying bands or chains which pass round a single pair of returning wheels only —that is to say, one at either end of the bands, and in which the edge or other part of the perforated trays is in a direct line between, and forms as it were a continuation of the pivots, on which they are suspended between the endless bands or chains, and in which the trays when lying horizontally do not overlap at their edges, and are therefore able to turn or drop clear of each other freely. The reason for this is that the above-mentioned arrangement for working the trays does not admit of their overlapping at their edges, as the overlap would be the wrong side up on the returning or lower stretch of the trays, and consequently the trays would not drop at the end of this return journey.

The under or returning horizontal stretches of perforated trays or troughs which hang swing-like below a direct line between the pivots on which they are suspended between endless conveying or carrying bands, moreover, are not utilised in combination with the dropping of the tea from the upper to the lower stretches so as to toss or turn the latter and thus hasten and facilitate its drying.

The use of the first-mentioned types of trays with their edges overlapping has been found to be very advantageous, because the overlap prevents the tea from dropping through between the trays, and should the trays get askew to one another by reason of the elongation of either of the conveying chains, the overlapping edges will accommodate themselves by slipping further or less into overlap, without fouling one another or sticking; whilst, on the contrary, with trays which do not overlap, the edges must be so closely butted to one another to prevent the tea from falling between them prematurely, that a slight elongation of either of the chains, or any tea getting jammed in between the edges, would cause them to stick and prevent their working properly.

The drying apparatus is constructed with endless conveying chains or bands which pass round returning wheels fitted with sprockets, or other suitable appliances for holding the chains in

position, which chains carry between them flat perforated trays arranged lengthwise in a direct line between the pivots which support them, and which when in their horizontal position overlap one another so that the leading edge of each tray will be on the top of the trailing edge of the tray preceding it, these trays being connected to the carrying chains or bands at the points of junction between the links of the chains, by pivots which project into sockets in the end frames of the tray, and are situated at one side of its centre of gravity, so that the tray will hang vertically when not supported. These trays and the endless chains or bands to which they are pivoted are supported along their upper stretch, in their forward movement, by horizontal rails or bars until such time as they approach the end of this movement, when the rails or bars terminate, and the trays as they successively pass beyond the termination of these rails will drop or turn on their pivots, and consequently discharge their contents, which will then fall on to the trays which are making the return movement along the under rails.

Whilst these trays and endless chains are passing downwards over the returning wheels, at the end of the upper or forward movement, each tray will be so acted upon by means of a fixed bar or other suitable obstruction that its lower edge will be projected over the upper edge of the tray next in front of it, thus reversing the overlap, which, with this type of overlapping trays, is absolutely essential to insure proper working, and which causes the trays when they reassume their horizontal position, and commence the return movement along the under rails, to have each their leading edge again on the upper side of the trailing edge of the preceding tray, the same as they have on their forward or upper movement on the top rails. The result of this will be, that when they reach the end of this return journey, where their supporting rails terminate in the same way as at the end of the forward movement on the top rails, the trays will again drop or turn on their pivots, and the tea will fall on to the proper surface of another similarly, constructed endless band of trays next below, or in the case of the last band to the outlet or discharge part of the apparatus.

Directly after thus discharging its load of tea, each tray will be then so guided that its upper edge will be projected past the lower edge of the tray next in front of it, so that in passing upwards

round the returning wheels at this end of the apparatus the overlap of the tray will again be so reversed that, on the trays being drawn

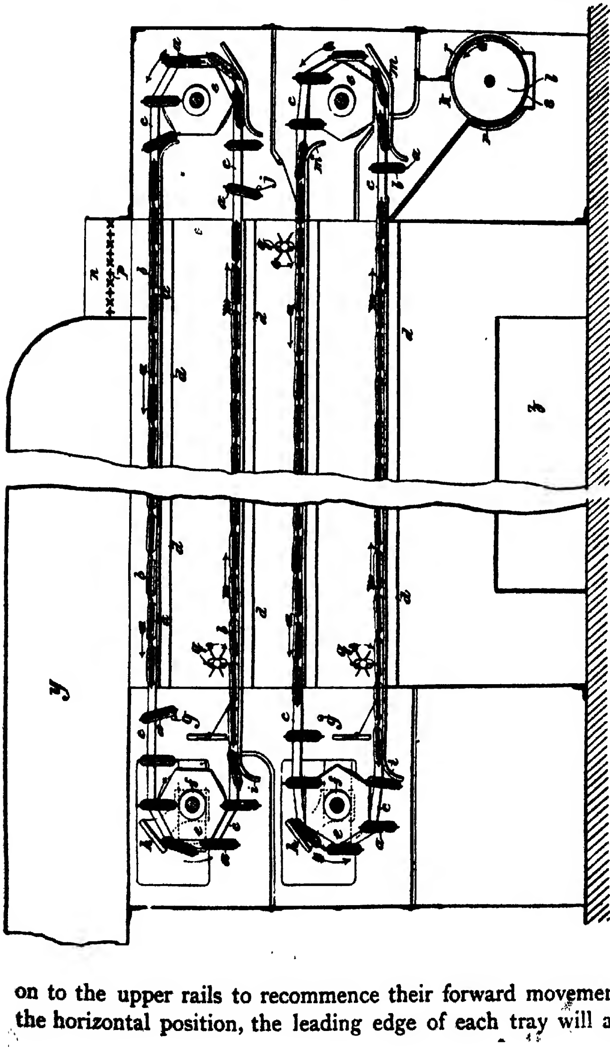


FIG. 67.—Automatic Down-draught Tea Drying Machine, with Two Superimposed Endless Bands of Flat Overlapping Trays or Plates (longitudinal section).

on to the upper rails to recommence their forward movement in the horizontal position, the leading edge of each tray will again

overlap the one preceding it, in the same way as it did at the outset of the movement.

In the above case the webs are supposed to pass round a single pair of returning wheels, one at each end of a double stretch. Where, however, the web is carried round more than two returning wheels, so long as the trays are descending to a lower stretch of the web the above-mentioned arrangement for bringing them from the first or top rails to the second or lower rails must be again applied, to bring them from the second to the third, and from the third to the fourth, and then, when they have again to ascend to the top rail or starting point, for adjusting the trays in their upward travel.

When the drying apparatus is constructed with endless conveying chains or bands carrying between them either flat or trough-shaped trays which are so pivoted to the endless chains, and are so suspended from their pivots, as to hang swing-like below a direct line between these pivots, so that their drying surface will remain horizontal, the supporting rails will only be necessary for the endless bands or chains, and need not touch the trays, which will swing clear of them, and will be consequently entirely supported by their pivots.

The swinging trays are supported on conveying chains which only pass round a single pair of returning wheels—that is to say, one returning wheel at each end of a double stretch of the chain; or they may be employed in conjunction with endless conveying chains passing round more than two returning wheels.

In operation, the swinging trays work practically in the same manner as the flat trays, whether the swinging trays and conveying chains pass round two or more returning wheels; but when the trays reach the end of their first forward movement they will be temporarily tilted or inverted so as to turn out the tea. This tilting can be effected by causing the trays to come against projections or stops, so that during their further onward movement the trays will be turned over by them, and after passing these stops will again fall into their horizontal position, and, descending round the returning wheels, move along the next under horizontal stretch with their edges again touching or overlapping, in which position they receive the tea which is tilted out of the trays which are travelling along the upper stretch. On

reaching the end of the lower stretch, these trays will be again similarly tilted, and may be carried downwards and either passed round another pair of returning wheels, or again up to the starting point. The tea that is tilted out of the trays in the lowest stretch will fall into the outlet or discharge part of the apparatus.

For the purpose of tilting or overturning the trays, V or T-shaped arms, so fitted upon the ends of the trays that their points project

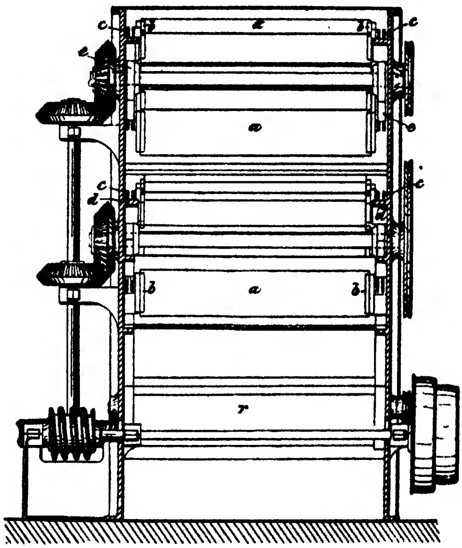


FIG. 68.—Automatic Down-draught Tea Drying Machine, with Two Superimposed Endless Bands of Flat Overlapping Trays or Plates (transverse section looking towards the front or feed end).

above the pivots on which the trays are suspended, are employed, the arms being also placed sufficiently beyond the extreme ends of the trays to avoid the possibility of coming in contact with the next nearest trays when they are swinging past one another while going round the returning wheels. The tilting or overturning of the trays is effected, during their forward movement, by the leading points of these V or T-shaped arms, on either the upper or the lower stretches, engaging with projections or stops attached to the sides of the drying chamber near the end of each horizontal stretch

of the trays, which stops turn the arms over, and thereby tilt the trays up on edge ahead of their pivots, and owing to the arms being V or T-shaped, this action will take place at the end of their return movement along the under stretch, the same as at the end of their forward movement along the upper or top stretch.

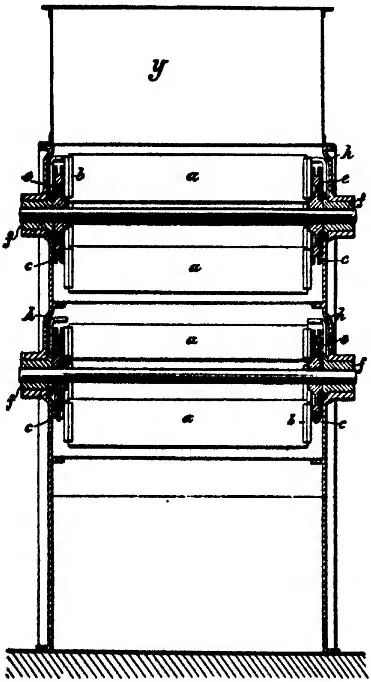


FIG. 69.—Automatic Down-draught Tea Drying Machine, with Two Superimposed Endless Bands of Flat Overlapping Trays or Plates (transverse section looking towards the rear end).

Upon the front or leading point of these tilting arms having passed the first stop, the trays will swing down slightly on their pivots, when this point will strike sharply against another stop with sufficient force to shake out any of the tea that may be inclined to stick to the tray, and this action may be repeated if more than one such knock is considered necessary to completely shake all the tea out of the trays. The trays are maintained in the tilted position by a bar-like elongation of the last stop, so as to allow each of the succeeding trays free room to be tilted in a similar manner without its striking against, or fouling with, its predecessor. After passing clear of this bar-like elongation, the trays will each in succession resume their normal hanging position, and begin to descend or ascend around the returning wheel, according to whether they are at the end of the forward or of the return movement of the conveying chains, after which they will be once more carried along the next horizontal stretch.

Heated air for drying the tea is passed downwards, which

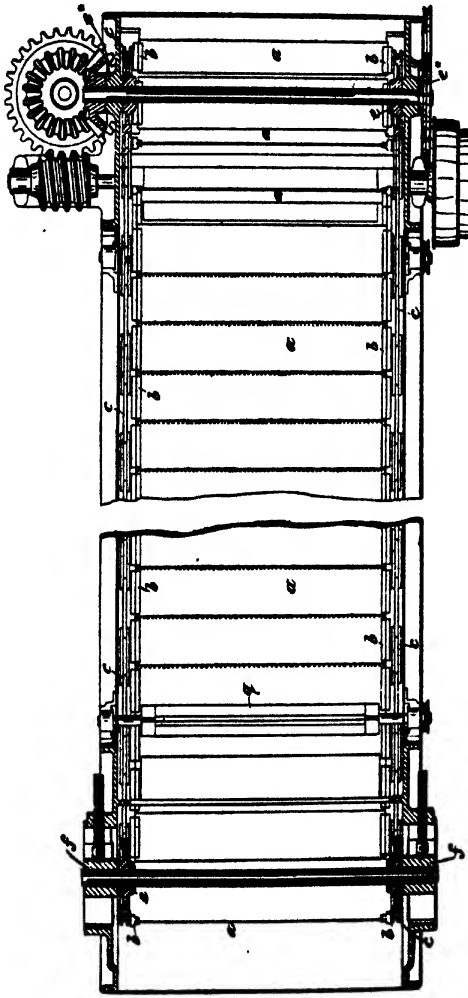


Fig. 70.—Automatic Down-draught Tea Drying Machine, with Two Superimposed Endless Bands of Flat Overlapping Trays or Plates (horizontal section).

admits of a much stronger air current being used than is possible when it is passed in an upward direction, in which case the current

must not be of sufficient strength to prevent the material falling down through it from the upper to the lower stretches of the trays.

Figs. 67 to 70 are various sectional views illustrating a pattern of drying apparatus in which the edges of the flat trays or perforated plates overlap one another, two superimposed endless bands of trays only being shown in this instance.

a are the transverse perforated flat trays, which are attached at their ends to holders *b*, pivoted to endless chains *c*, the pivots being sufficiently near the leading edge of the trays to cause the trays to drop or tilt into a vertical position when not supported. The holders *b*, and endless chains *c*, travel along and are supported by rails or bars *d*, both in their upward forward movement and in their lower return movement, and at the two ends of their course the chains pass over wheels *e*, from either one of which the chains receive their motion. *e** are fixed bearings supporting the spindle of the wheels *e* at the driving end of the machine, and *f* are the movable bearings carrying the spindle of the returning wheels at the opposite end of the drying chamber *h*, which latter bearings are adjustable by means of screws for the purpose of tightening or slackening the chains *c*, as clearly shown in Fig. 70.

The wheels *e*, at one end of the apparatus are driven by a combination of worm and bevel gearing (Figs. 68 and 70).

The upper rails *d*, are discontinued, as shown, near the end of the upper forward movement of the endless bands so as to no longer support the latter; and similarly, near the end of the lower return movement, the lower rails *d*, are discontinued with the same object (Fig. 67).

As clearly shown in the drawing, the leading edge of each tray at the upper part of the endless bands is arranged to overlap the trailing or rear edge of the tray next in front, so that each tray is perfectly free to drop or tilt on its pivots when clear of the support of the upper rails *d*, and, moreover, so that at the lower or return part of the endless bands the leading edge of each tray will again overlap the trailing or rear edge of the tray next in front, and thus each tray be again free to drop or tilt on its pivots as soon as it passes the lower rails *d*.

The overlap of the trays, however, must be reversed between the termination of the upper rails and the commencement of the lower rails, otherwise the leading edge of each tray would be under

the trailing or rear edge of the tray next in front, and consequently the trays would be prevented from dropping or tilting on their pivots on passing the lower rails.

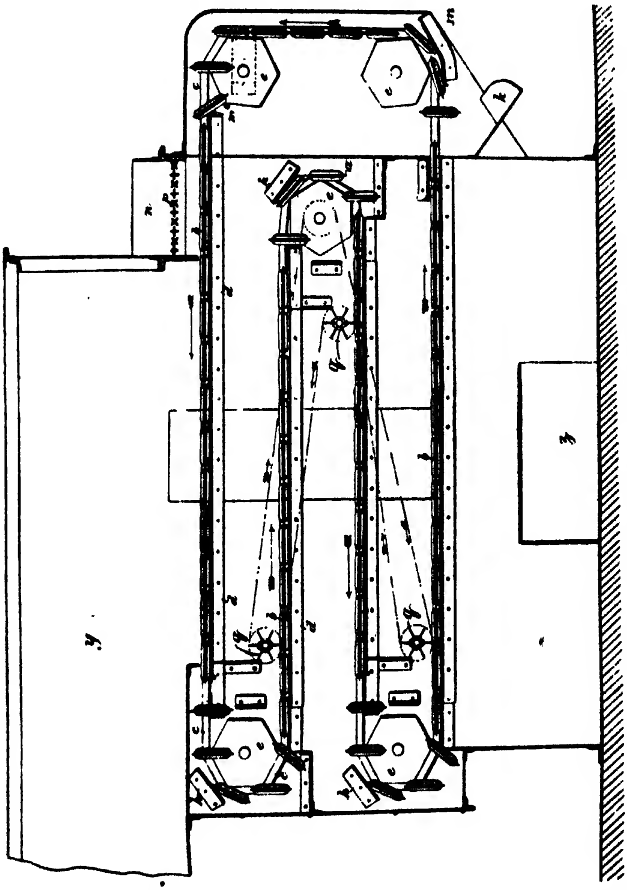


FIG. 71.—Automatic Down-draught Tea Drying Machine, with Flat Trays or Plates, and One Continuous Tray or Plate Web (longitudinal section).

This reversal of the overlaps is effected as each tray gets clear of the end of the supporting rails *d*, and its holders *b* tilt or drop backwards on their pivots from the horizontal position against a projection or stop *g*, which it strikes, generally with sufficient

force to shake off any tea which may be adhering to the trays, and which, by the dropping of the tray, will fall on to the under or returning trays of the endless band.

The tray and its holders after travelling clear of the stop *g*, will fall, by reason of gravity, into the vertical position shown in Fig. 67, which position will be retained until the holders come in contact with a projecting bar *h*, by which the tray and holders will be turned into a position which throws the lower edge of one tray over the upper edge of the one next in front—in fact, produces a reversal of the overlap of the two trays.

As soon as the bar *h*, has been passed, the tray and holders again assume the vertical position, which position they will retain until the holders come in contact with the guides *i*, at the commencement of the lower rails *d*. These guides will cause the tray and holders to move into a horizontal position, the leading edge of each tray overlapping the trailing edge of the tray next in front, as shown.

On leaving the other ends of the rails *d*, the trailing edge of the tray and holders will again drop downwards against a projection or stop *j*, which it also strikes with sufficient force to shake off any tea which may be still adhering to the tray, the tea on the latter being discharged by the dropping of the tray and falling on to the upper surface of the trays of the endless band next below, or in the case of the last band through an opening *k*, into a discharge drum *l*.

The tray after passing the stop will again assume a vertical position, which it will retain until each tray and its holders come into contact with a guide bar *m*, which so controls the movement of the tray, that when it meets another guide *m**, its upper edge will be projected past the lower edge of the ascending tray immediately preceding it, and the overlap be thus once more reversed, so that on the trays being drawn on to the upper rails, to recommence the forward movement, in the horizontal position, the leading edge of each tray will overlap the trailing edge of the one preceding it.

Wheels *q*, are provided to spread any of the tea that may fall upon the trays in mounds or lumps. These spreaders consist of vanes formed of pieces of thin sheet-iron having blocks or distance pieces between to which they are fastened, and which blocks are attached to the spindle. They are arranged to revolve in an opposite direction to the direction of motion of the trays,

and they are mounted in slotted adjustable bearings, which arrangement admits of their being raised or lowered according

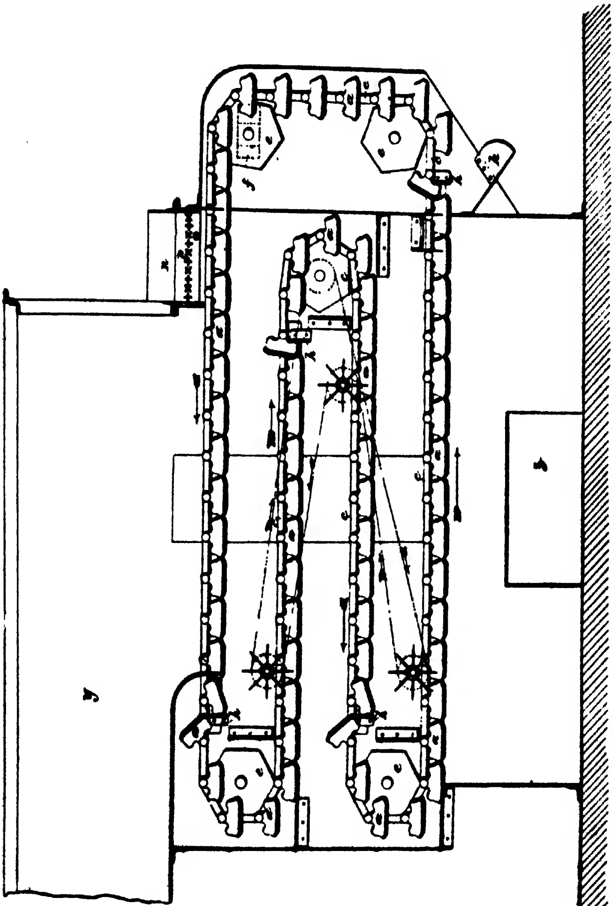


FIG. 72.—Automatic Down-draught Tea Drying Machine, with One Continuous Tray or Plate Web and Swinging Trays (longitudinal section).

to the thickness, or depth, of the layer of tea that is to pass underneath them.

The tea is supplied to the uppermost endless band by a feeding or

spreading arrangement, comprising a feed hopper *n*, and either cruciform or three-edged bars *p*, which have a reciprocating rotary motion imparted to them.

The dried tea is delivered or discharged from the apparatus by means of the before-mentioned revolving drum or cylinder *l*, which has a segmental portion of its circumference removed, so as to form an opening of suitable dimensions to admit the tea from the aperture *k*, to the interior of the drum or cylinder *l*. This latter is partially inclosed by a loose-fitting cover *r*, which forms a discharge outlet *s*, which, when the opening in the revolving drum *l* is brought opposite to the opening *k*, allows the tea to fall through into the revolving drum, and when the opening in the drum is brought opposite to the discharge outlet *s*, allows the tea to fall out of the drum, and to be thus discharged without admitting any air into the apparatus from the exterior, or permitting the escape of any hot air out of it.

In the drying apparatus shown in Fig. 71, the endless bands are arranged as one continuous web from start to finish, so as to give four lines of drying surface, the trays being tilted at the end of each line, as above described, and the tilting trays, on leaving the lowest line, passing vertically to the top line to resume their operative position.

The discharge outlet *k*, for the dried material is in this case in the form of a simple chute.

In Figs. 72 to 75 are shown two patterns of drying machines in which swinging trays are employed. The trays of this type of machine, it will be seen on referring to Fig. 72, hang swing-like on their pivots by their own gravity, so that their carrying surfaces will be horizontal, and they do not themselves require to rest on guide rails such as those shown in the previously described machines. The only parts that have to be supported by guide rails are, therefore, the links of the endless chains *c*, the trays between them hanging in such a manner as to swing freely on, and below a straight line between, their pivots. In this example a continuous web is employed.

When the trays successively reach the end of each horizontal travel, the forward motion of the chain will bring the edge of the tray against a stop *h*, which causes it to become inverted, the tea being thus turned out so as to fall on the line of trays below; and the trays on passing the stop *h*, being, if found desirable, arranged

to strike against a second stop, or a series of them, with sufficient force to shake off any tea that may still be adhering to each tray.

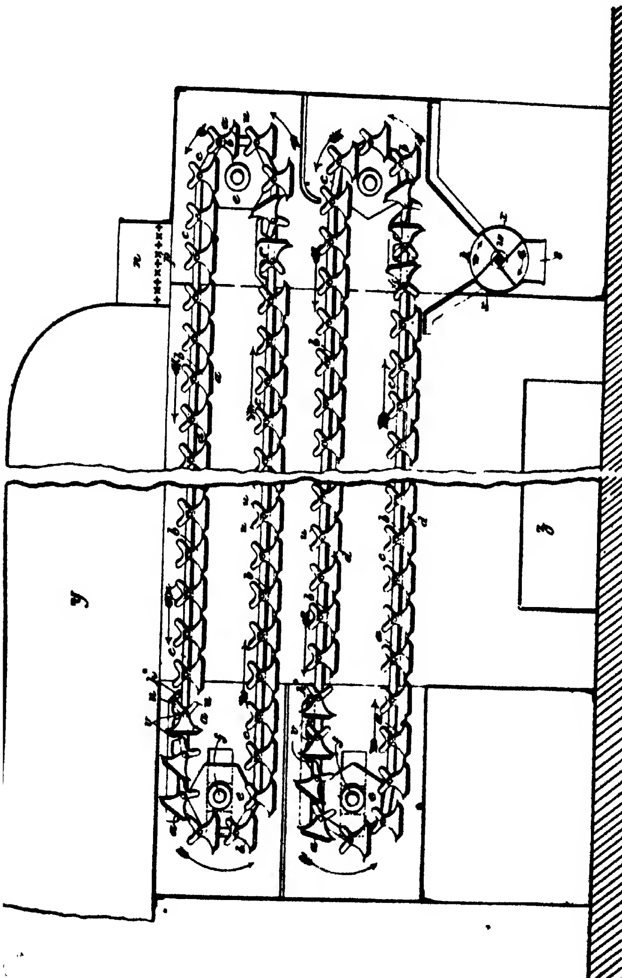


FIG. 73.—Automatic Down-draught Tea Drying Machine, with Swinging Trays or Plates having V-shaped Arms or Projections (longitudinal section).

On passing the last of these stops, each tray will again resume its normal horizontal position under the action of gravity.

Figs. 73 to 75 illustrate a pattern of swinging-tray drying machine with trays having V-shaped arms or projections *u*, the leading points of which come against the projection or stop *h**, which causes the trays to tilt in the manner shown. After passing

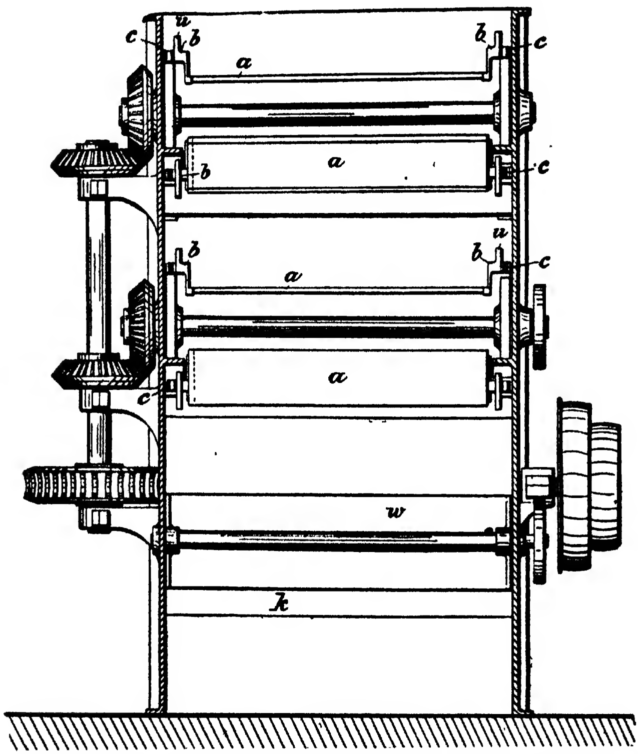


FIG. 74.—Automatic Down-draught Tea Drying Machine, with Swinging Trays or Plates having V-shaped Arms or Projections (transverse section).

the stop *h**, the trays will swing down a little, and the leading points of the arms *u*, strike against the stops *v*, with sufficient force to shake out any of the tea that may still be sticking to the trays; the last of the stops *v*, being elongated so as to keep each tray after it is clear of it in a tilted position for a sufficient length

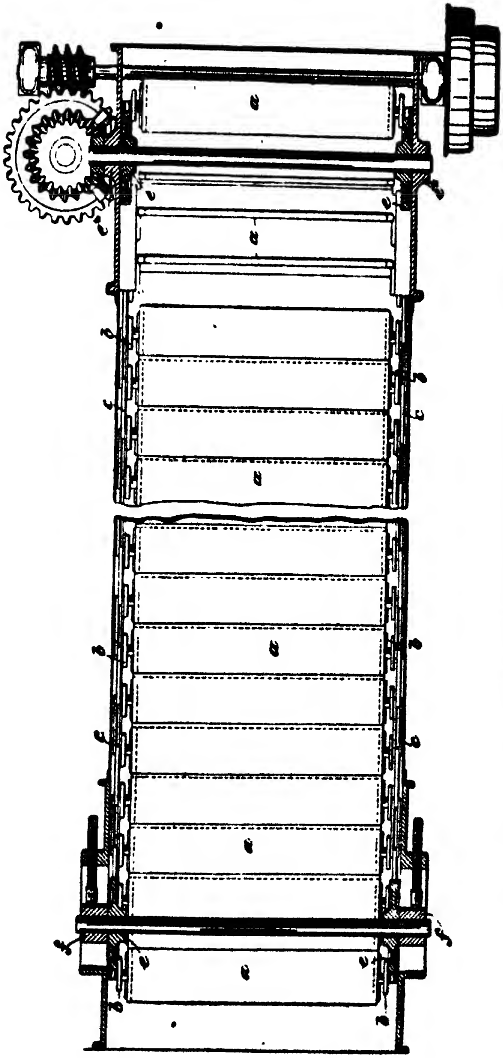


FIG. 75.—Automatic Down-draught Tea Drying Machine, with Swinging Trays or Plates having V-shaped Arms or Projections (horizontal section).

of time to allow free room for the next succeeding tray to tilt in a like manner without striking against the tray in front of it.

The swinging trays are made either trough-shaped or flat, and of sufficient width to allow of their edges slightly overlapping one another.

The tea is discharged from the drying machine without admitting any air, by means of the arrangement clearly shown in Fig. 73, which consists of a number of revolving vanes *w*, fitted on a spindle and partially inclosed inside a loose-fitting cover *x*, in such a manner that the opening *k*, and the outlet *s*, are formed in this loose cover. The tea dropping from the trays into the opening *k*, will fall upon the revolving vanes *w*, which, on passing round to the outlet *s*, will discharge it without admitting any air to the interior of the machine.

The heated air for drying the tea on the trays is passed, in all of the above-described drying machines, vertically downwards through the travelling trays, the tea being delivered into the drying chamber above the top row of trays, through an inlet duct *y*, and the air after passing through the trays, escaping through an opening, marked *z*, located below the bottom row of trays.

An advantage peculiar to the system of drawing the air current down through the trays is that it does not disturb the tea thereon, when using a strong air current produced by a fan.

The method of working employed in the drying machines illustrated in Figs. 67 to 72, for effecting the reversal of the overlap of the trays when passing round the sprocket wheels on which the endless webs are mounted, has been found in practical operation to be occasionally liable to derangement, owing to strings or other obstacles of a like nature getting in with the tea to be dried, and by such foreign matter becoming entangled with the trays at the place where they swing down and effect their change of overlap, preventing them from passing their edges from the correct overlap for the top surface to that for the lower one.

In the machine illustrated in Figs. 76 to 84, the reversal is effected by the positive action upon the trays of specially-shaped projecting ledges or rims on the sprocket wheels round which the endless chains of the trays pass, or on a separate wheel on the same spindle, which engage the end holders of the trays or the

trays themselves, and absolutely compel the trays before descending to the under stretch of the endless web, or ascending back

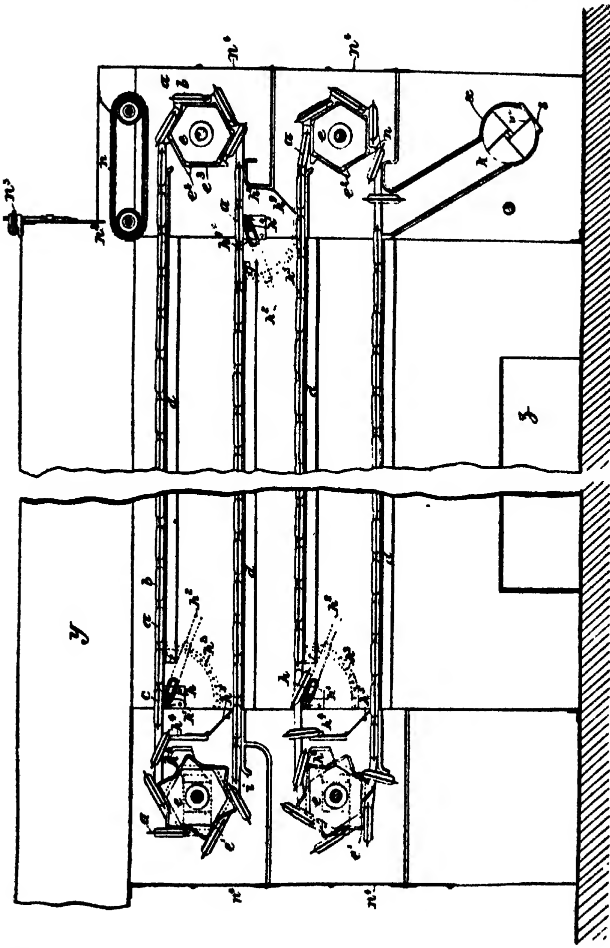


FIG. 76.—Automatic Down-draught Tea Drying Machine, with Positive Reversing Movement of the Trays (longitudinal section).

again to the upper stretch, to reverse the overlap of their edges, without having to depend on any gravitating or swinging motion of the trays themselves.

From this it will be obvious that if the projecting ledges, rims, or arms which effect the reversal of the overlap of the edges of the trays, after dropping their contents and before passing round the sprocket wheel, be applied on a separate wheel keyed on the sprocket wheel shaft, the same results will be accomplished as when they are attached to the sprocket wheel itself, as before described. The latter arrangement, however, being the most convenient method, is the one which is the most usually employed.

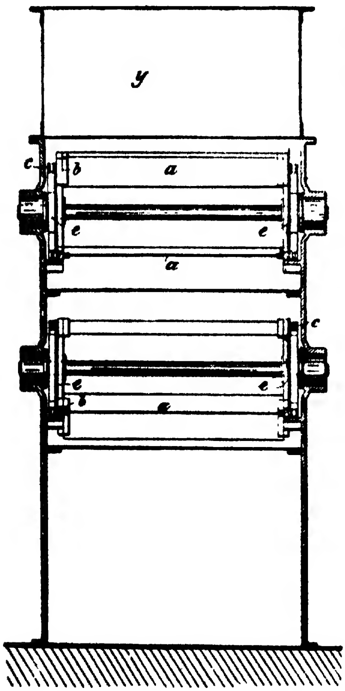


Fig. 77.—Automatic Down-draught Tea Drying Machine, with Positive Reversing Movement of the Trays (transverse section, looking to the rear end).

An even distribution of the material when discharged by the trays upon the surface of the endless webs immediately below is effected by giving the trays two or more drops in stages, the first of which is so regulated by the position of an adjustable stop or bar against which the tray falls that the tray will drop to such an angle as to cause the tea upon it to be only partially discharged on to the surface below, after which the tray, on being drawn forward clear of this stop or bar, will again fall against another stop or bar, which is so placed as to come in contact with the tray, when the latter is in a vertical position, and thus discharge the remainder of the tea. To effect a further spreading of the tea, another drop between the above two may be provided, the stop or bar being in this case so placed that the tray will drop to such an angle that a further portion only of the tea left upon it after the first drop will be discharged.

As will be seen from the illustrations, the leading edge of each tray in the horizontal stretches of the endless webs is arranged to overlap the trailing or rear edge of the preceding tray, and each tray will be free to drop on its pivots, when the support of the rails ceases, on the upper or lower stretches respectively.

On passing the end of the supporting rails, each tray will drop downwards from the horizontal position and strike against the adjustable stop *h*, the tray only dropping to a sufficient angle to partially discharge its load of tea on to the trays below. The stop *h*, is carried upon a spindle h^1, and can be adjusted or regulated by a handle h^2, from the outside of the machine, a quadrant h^3, being provided for locking it in the desired position. The range of adjustment of this stop is such that the tray may be allowed to drop to any required angle between the horizontal and vertical, as the tea will vary in its degree of dampness, and will consequently require different adjustments of the angle to effect this partial discharge.

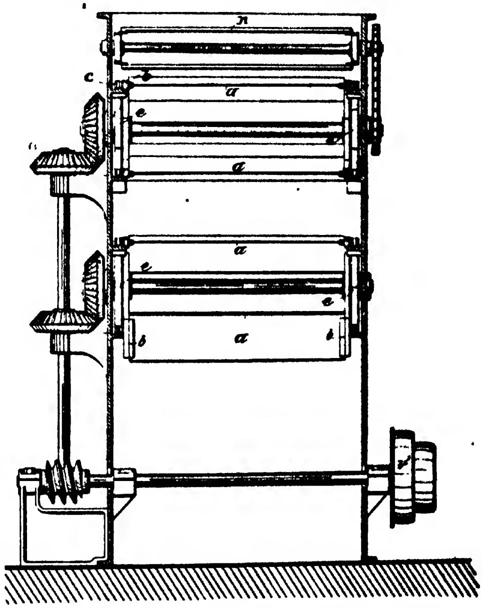
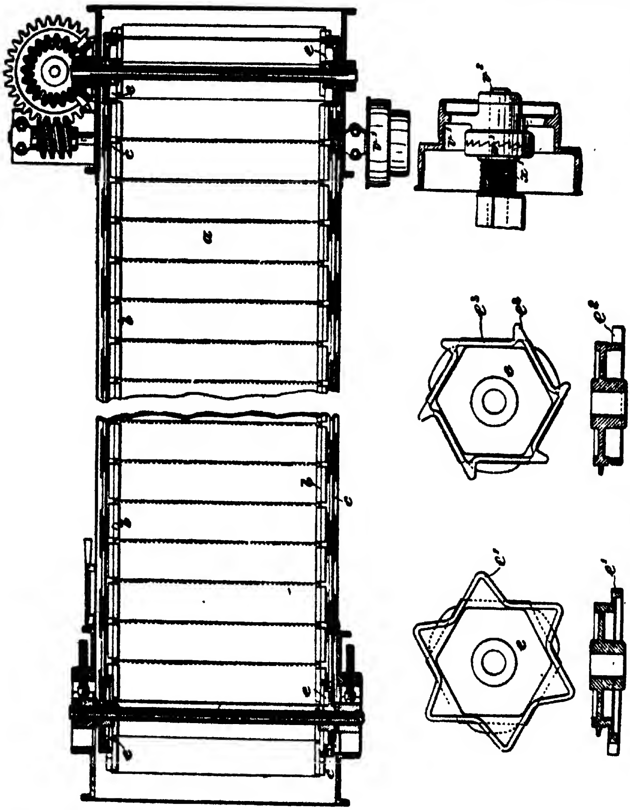


FIG. 78.—Automatic Down-Draught Tea Drying Machine, with Positive Reversing Movement of the Trays (transverse section, looking to the front or feed end).

A glass door provided in the side of the machine enables the stop to be set correctly and the discharge to be observed whilst the machine is at work.

As soon as the tray has passed over the stop h, it drops to a vertical position against the stop h^4, with sufficient force to shake off the remainder of the tea.

This discharging of the tea from the trays in instalments effects



Figs. 79 to 84.—Automatic Down-draught Tea Drying Machine, with Positive Reversing Movement of the Trays (horizontal section and details of construction).

a more equal distribution of it over the trays below than would be the case were it all dropped at one time; the remainder of the tea discharged at the second drop of the tray falling on a hinged flap or apron h^5, attached to the stop h^4, slides down upon the under or returning trays of the endless webs, and thus further assists in effecting an even spreading of the material upon them. The tray

after travelling clear of the stop h^4, then strikes against the stop h^6, which is attached to and moves with the movable bearing of the sprocket wheel *e*, so that as the said sprocket wheel is moved forward or backward by the adjusting screws to tighten or slacken the chains carrying the trays, this stop will always maintain the same relative position with regard to it, and will guide the trays correctly on to the projecting rims or ledges e^1, of the sprocket wheel, a further revolution of the wheel causing these projecting rims, owing to their special shape, to tilt the trailing edge of each tray above the line of the top horizontal stretch of trays, and thus to reverse the overlap of the edge of the tray from what it was in the said top horizontal stretch or web, the trays being then carried round with the sprocket wheel in this same relative position to one another, until the chain, on leaving the wheel, draws the trays forward over the guide *i*, on to the rails *d*, into the horizontal stretch of trays which forms the under or returning web, with the overlap of the leading edge of each tray on the top of the trailing edge of the tray in front of it.

Previously to the trays ascending back to the top stretch of the endless web, at the opposite end of the under web, the trailing end of each successive tray, on reaching the end of the guiding or supporting rail will drop against a stop h^7, which is adjustable in a similar manner to the stop *h*, and is also so arranged as only to partially discharge the tea from the trays, and after travelling clear of this stop h^7, the trays will successively drop into a vertical position against the stop h^8, and discharge the remainder of the tea over the apron h^9, after which the chain will successively draw the trays again into a horizontal position over the horizontal supporting ledge of the stop h^8, the length of which is such that the pivot of the tray will have just cleared its rear end as the following tray reaches its front end, the nose or point e^2 of the projecting ledges e^3, of the sprocket wheel then bearing down on the leading end of the tray or its end holders, and forcing it past the rear end of the stop h^8, so as to tilt the trailing end of each of the trays up clear of the leading end of the tray following, and to reverse the overlap of their edges, the trays being then held in this same relative position to one another by the projecting ledges e^3, whilst passing round the sprocket wheel, so that when drawn by the chain on to the top rails *d*, the overlap of the

leading end of each of the trays will be on the top of the trailing end of the tray preceding it. The sprocket wheels are shown more clearly in the detail views, Figs. 80 to 83.

The dropping tray will discharge its entire load of tea at one single operation in the lower or returning stretch of trays in the lowest of the endless webs, the tea falling into the discharge chute, and passing through the aperture *k*, to the discharge wheel *w*, by which it is delivered out of the machine.

The feed inlet to the machine is fitted with a feeding or spreading apparatus consisting of an endless band of flat laths *n*, carried upon chains running upon sprocket wheels, one of which is driven by means of a chain from the spindle of the upper endless band. The thickness of the layer of tea fed into the machine can be regulated by the inlet door n^1, which may be raised or lowered by means of the worm gear n^3; n^4 are doors provided for admitting of an examination of the various parts of the interior of the machine being made when required.

To render the starting of the machine in the wrong direction, and the consequent damage to the trays an impossibility, the driving pulley is fitted with the clutch shown in Fig. 84; v^1 is the driving pulley which runs loose upon the shaft v^2; w^1 is a clutch, one part of which is keyed on the shaft v^2, but is free to slide in and out of gear, and is nominally kept in gear with the other part on the driving pulley by the spring x^1. It will be seen that this clutch can only drive the machine in one direction, and that if the driving pulley be rotated in the opposite direction to that in which the clutch is intended to operate, it will come out of gear.

The heated air being introduced into the machine from the top, the tea will be subjected to an inverted system of drying, by which the wet or moist fermented leaf upon passing into the drying chamber will be instantly acted upon by a blast of fresh heated air arriving direct from the air heater, in which manner it is claimed that all tendency of the leaf to undergo any further fermentation will be immediately stopped.

The characteristic feature in this inverted system of drying the leaf, it will be seen, is the carrying of the latter through the drying chamber on travelling webs or bands of tilting trays, and from the moment at which the moist leaf enters on the upper web of trays, exposing it to the action of the fresh hot air arriving from

the air heater, during the entire stretch of the top web or band to the opposite end, where it will fall on to the returning stretch of the same web, and will pass into a temperature which, by reason of the air having already traversed the layer of leaf on the upper or top stretch, will be considerably lower. This action will be repeated right through the apparatus, as the leaf falls from stretch to stretch of each web downwards, and it will become further and further dried, and at the same time gradually enter into relatively cooler temperatures, being finally discharged from the machine as dried tea, and quite cool to the touch.

It is further claimed for the inverted system of drying, by first passing the moist leaf into the hottest air from the air heater, and subsequently into successively lower temperatures, as the drying leaf gradually gives up its moisture, that it admits of the complete desiccation of the leaf, and that the conversion of the latter into finished tea can be automatically completed without any risk of over-firing or burning. This action is, moreover, stated to be practicable even in cases in which the amount of moisture in the leaf subsequent to the withering and rolling operations varies from time to time during the day, all that is necessary to insure success being to so regulate the speed of discharge or output from the machine, that the leaf which contains the maximum quantity of moisture will have sufficient time to get completely dried before being so discharged, whilst, in the event of a charge of leaf of a more highly withered and drier description following directly on that of one overcharged or surcharged with moisture, no danger of the former being over-fired or burnt can arise, inasmuch as the finishing temperatures, whilst yet capable of absorbing or taking up moisture, are notwithstanding comparatively low, being practically that of the air passing away through the exhaust fan, and consequently perfectly safe, and that no matter how long the finished rough tea may have to remain exposed to it after having become fully dried.

In the latest pattern of machines the tray web chains are driven in such a manner from the cone pulley gear, that the top web or band in each case will travel at a greater speed than the one immediately beneath it, so as to give the moist or saturated leaf, a faster rate of travel through the strong heat, and the tea is arranged in thin layers so as not to materially obstruct the passage

through it of the current of air. A slower rate of travel and thicker layers being provided whilst passing through the cooler or lower temperatures on the lower webs, upon which the leaf, becoming further dried, will rest more loosely and openly, so that the additional thickness of the layers does not offer any additional obstruction to the air current.

In fact, this different motion of the tray webs or bands, serves to keep the leaf in the machine so much longer, in order to finish off its drying at the lower temperatures, that it becomes equivalent to the provision of an additional web of trays, as compared to an arrangement in which all the trays travel at the same rate of speed in the drying chamber.

The drying chamber is fitted with an exhaust fan, having a propeller vane intake and a centrifugal delivery, which being mounted on a heavy cast-iron bracket and base-plate alongside the drying chamber, and on the floor, insures absolute steadiness in driving, and does not tend to strain or cause any vibration of the drying chamber when at work. This fan is so arranged as to draw the heated air from the furnace or stove down through the layers of leaf upon the trays.

The cone pulleys driving the tray chains have five different speeds, so adjusted that the time occupied by the leaf in passing through the drying chamber can be arranged to be either 13, 18, 22, 26, or 30 minutes, in accordance with the size of the pulley upon which the driving belt is placed.

It has been found, from actual practical working experience upon a tea plantation, that one of these machines is capable of turning out on an average about four maunds (320 lbs.) of fully dried tea per hour, the tea coming out evenly and perfectly fired, and the stoking of the air heater or stove giving no trouble. On many days the output of fully dried tea was 50 maunds (4,000 lbs.) per day, and the machine was found capable of drying a very large quantity of tea to about 12 annas,[1] or to 75 per cent.

The fuel consumption has been found to be about a pound of half-dried wood, consumed in the air heater or stove furnace, to

[1] The native method of reckoning all fractions as part of a rupee, hence as a rupee equals 16 annas, 4 annas means 25 per cent., 8 annas 50 per cent., 12 annas 75 per cent., and so on.

each pound of tea turned out of the drying machine, but the amount of fuel burnt, will, of course, vary with the quality of the fuel employed.

The air heater, or stove, used in connection with this drying machine, which stove is illustrated in Figs. 85 to 88, is one of very ingenious construction, and it is also the invention of the same gentleman as the drying chamber.

It is built entirely of iron, requiring no brickwork of any description whatsoever. A special smoke consuming appliance is fitted in the central furnace, with the result that, except for a few moments after fresh coal or other bituminous fuel has been thrown

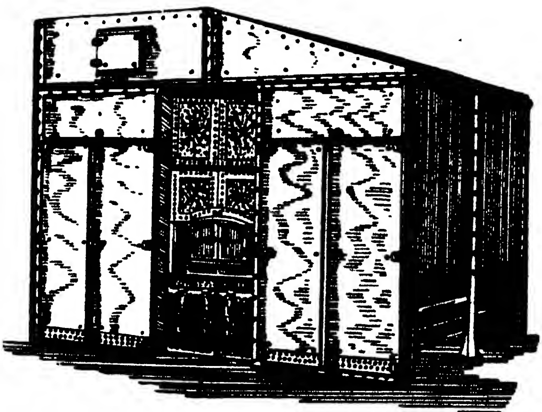


FIG. 85.—Air Heater or Stove for Use with Tea Drying Machines (front perspective view).

into the furnace, hardly any smoke will be visible, and with wood fuel scarcely any smoke will be ever seen to issue from the chimney.

Fig. 85 shows a front view in perspective of this air heater or stove, and its inclosing casing, complete.

Fig. 86 is a similar view of the same air heater or stove with the casing removed, so as to allow its interior construction to be seen, the door of the front right hand smoke chamber or box, moreover, being thrown partly open to show the tube caps or nuts protecting and holding the extremities of the tubes, by giving which caps or

nuts a quarter turn they can be removed, and the tubes can then be easily withdrawn.

Fig. 87 is a rear perspective view of the air heater or stove, the outer casing being removed, and one of the upper back smoke chamber or box doors being partially opened to show that portion of the interior where the smoke enters from the back end of the central furnace. And Fig. 88 shows in perspective the arched-over central furnace only partially erected, so as to allow the arrangement of the heavy arched bars and the general construction to be seen.

The arched-over furnace forms the central part of the air heater

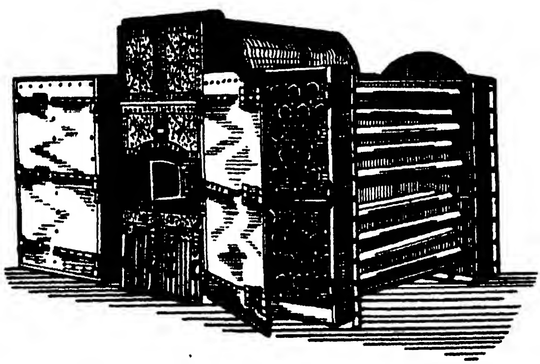


FIG. 86.—Air Heater or Stove for Use with Tea Drying Machines (front perspective view with outer casing removed).

or stove, and the smoke from it passes from its posterior end into the upper compartment of the rear right and left hand smoke chambers or boxes, from which it is next conducted into the upper part of the front smoke chambers or boxes through the uppermost section or set of tubes, which consists of five rows, then descending through the front boxes or chambers to the lower section or set of tubes, which consists of four rows; it next passes through these latter to the lower compartments of the rear smoke boxes or chambers, and finally from thence escapes into the chimney.

As will be seen from the illustrations, the front and rear tube-plates and the smoke boxes or chambers are fitted with hinged

doors, which, when the corresponding doors, which are provided in the outer casing exactly opposite to the first ones, are opened, can be swung freely in an outward direction so as to expose the tube-plates and tube ends, and thus admit of easy access being obtained thereto for cleaning purposes, or for the renewal of any particular tube or tubes should it be found necessary at any time to do so.

The upper compartments of the rear smoke boxes or chambers are cut off from the lower ones by dividing plates or diaphragms, thus forcing the waste products of combustion to pass from the

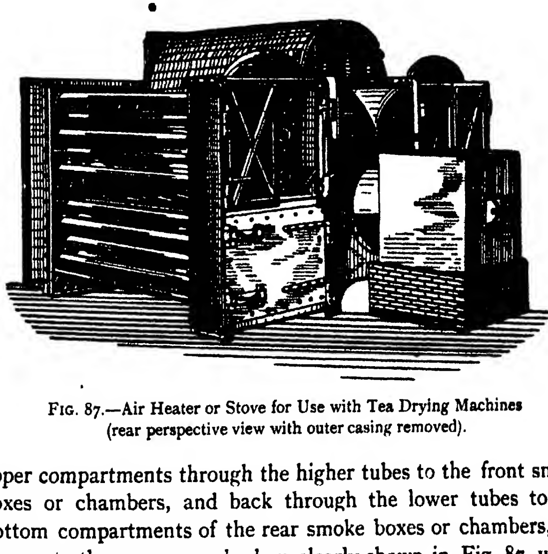


FIG. 87.—Air Heater or Stove for Use with Tea Drying Machines (rear perspective view with outer casing removed).

upper compartments through the higher tubes to the front smoke boxes or chambers, and back through the lower tubes to the bottom compartments of the rear smoke boxes or chambers, and thence to the square smoke box clearly shown in Fig. 87, which forms the base of the chimney.

The upper rear smoke boxes or chambers are fitted with double cast-iron doors, which are made in two parts, and are of considerable strength, to prevent warping, but as the heat in the lower rear smoke boxes or chambers will be comparatively low, single doors of metal plate are here found to be all that is required.

It will be seen that the effective heating surface provided by the above described multitubular air heater is very extensive, and that

it is consequently capable of raising the temperature of large volumes of air up to the requisite degree.

The air to be heated enters at the aperture in the outer casing shown in Fig. 85, near the bottom of the end which is situated the furthest from the leaf drying machine, and after passing over the tubes, furnace, and other heating surfaces, enters the drying chamber through a connecting trunk or flue.

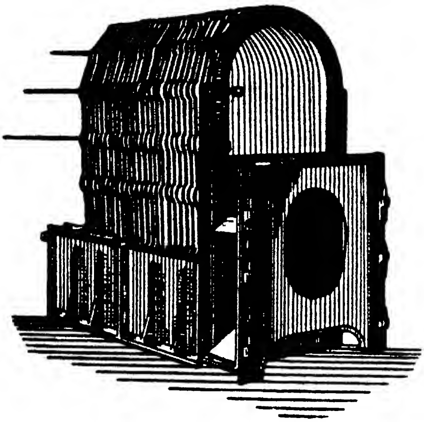


FIG. 88.—Air Heater or Stove for Use with Tea Drying Machines (perspective view of arched-over furnace).

The largest size made of this pattern of stove weighs 9 tons 10 cwts., exclusive of packing.

The approximate dimensions of one of Davidson's automatic down-draught drying machines, fitted with a multitubular air heater or stove of the type which has been just described, are: length 25 ft. 3 ins., width 21 ft. 1 in., and height 8 ft. 1 in.

Automatic Up-Draught Tea Drying Machines.

A number of tea drying machines on the up-draught principle have been devised by inventors. In one of several machines designed by H. Thompson, the tea is exposed in a chamber through which hot air is drawn by a fan. The trays are inserted near the top of the drying chamber, and are gradually moved downwards by mechanical means until such time as they reach a discharging aperture at the bottom. To effect this purpose the trays are supported at each side by projections on chains which pass round wheels rotated at a slow speed by suitable gearing; or in another arrangement, the trays are supported in grooves and

moved by chains. When a tray reaches the end of one groove it falls down to the level of the next, and is carried back along that.

Three other patterns of machine comprise, the first, improvements in the endless band-method, which consist in so constructing the bands with trays that both the upper and lower parts of them may be employed to carry the tea.

The machine consists briefly of a drying chamber in which are mounted pulleys carrying chains to which are hinged by pivots perforated trays supported horizontally, except near the ends of the lines of trays, by horizontal bars. Near each end the trays tilt and drop the tea upon the trays beneath.

The tea is fed on to the upper tray from a hopper by a corrugated roller and a kicking bar.

The second machine has chain wheels carrying endless bands, or chains to which tilting trays are attached, located outside the drying chamber and inclosed in casings, that at one end being extended so that its cover forms a hopper or feed inlet, and its bottom a discharge outlet.

A stove or heating apparatus located below supplies the necessary hot air, the heating of the latter being effected by passing the products of combustion through chambers traversed by tubes through which atmospheric air passes to a central chamber and thence upwards into the drying chamber.

Baffle plates are also provided to deflect any tea that may drop from the trays, and to prevent it from falling into the heating apparatus.

Fans situated on the upper part of the drying machine exhaust and distribute the heated air.

The above apparatus is intended to be driven by hand power. When it is arranged for power the heating apparatus consists of a chamber through which the air is passed, containing a number of double plates communicating with one another, between which the products of combustion pass to the chimney.

The drying trays are provided in this case on one side with a rim, or T-shaped edge, formed by bending the sheet of metal of which the tray is made, and the pivots about which the trays turn take into tubular rivets which connect the links of the chain.

In the third machine the tea is fed to a number of rotary trays

mounted on horizontal shafts in a chamber which is supplied with hot air from tubes fixed in a furnace, as well as from a device consisting of an annular chamber surrounding the chimney of the furnace and containing a spiral division plate.

The tea falls from layer to layer of revolving trays, and is finally conveyed away by an endless band conveyer.

Rotation is communicated to the tray shafts by eccentrics fixed to the frames in which the cranked ends of the shafts are journalled.

A fan connected with the space below the first layer of trays serves to withdraw the moisture-laden air.

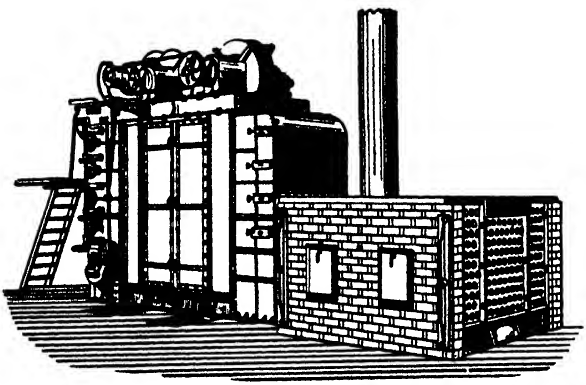


Fig. 89.—Automatic Up-draught Tea Drying Machine with Double Action Bands or Webs.

The uptake flue is arranged to surround the furnace chimney so as to increase the draught through the drying chamber.

Thompson's tea drying machines are constructed by Ransome, Sims & Jefferies, Ltd., Ipswich, Fig. 89 illustrating the principal pattern of machine at present built by them.

In this drying apparatus the leaf is carried upon double action bands, or travelling webs, the use of which is claimed to give double the drying surface in the same amount of space that could be obtained by the use of single-action band or webs, in which the trays on the back travel are forced to hang in a vertical position and would be consequently out of operation.

In the dryer under consideration are mounted four sets of

endless chains, or eight lines of trays. The leaf is carried by the bands or webs during their travel both in a forward and backward position, the trays, of which the bands or webs are composed, tilting, and quickly dropping the tea that is upon them on to the line of trays beneath, at each end of the machine.

The rolled leaf is fed on to the travelling webs or bands by means of a mechanical feeder, being continuously discharged at the end of the machine, the leaf being turned eight times during its passage through the machine, which action insures an exposure of all sides of the leaf to the current of warm air passing through it and upwards to the fans, two of which, fitted with special air trunks, are provided.

It is claimed that the use of two fans insures a more even ascent of the heated air through the perforated trays than it would be possible to effect with a single fan, every inch of drying surface being made use of, and a practically complete uniformity of temperature being maintained in every part of the machine.

The chains carrying the trays are each driven by a separate pair of bevel or mitre wheels, as is clearly shown in the illustration, and the necessity for complicated trains of gear wheels is thereby dispensed with, thus getting rid of the transmission of the strains through one chain wheel shaft to another.

The change speed, or cone pulleys, fitted to the main shaft allow of the employment of any one of five speeds being made so as to enable the duration of the drying process to be varied from 6½ to 18 minutes.

The fan shaft is run at a speed of about 500 revolutions per minute, the main fast and loose pulleys being ten inches in diameter, with a face surface to take a belt four inches in width. The power required to drive this machine would be about 1½ h.p.

The air heater or stove employed with the above dryer is of the multitubular type, and its construction will be readily understood from the drawing without further description. It will be seen that it is so arranged as to be very readily accessible internally for cleaning or repairs, and it is located, as shown, at the rear of, and on a level with, the dryer.

The capacity of this dryer is stated by the makers to be somewhat above four maunds (320 lbs.) of perfectly or fully

fired (pucca) tea per hour, the output of tea fired to 65 or 90 per cent. being of course correspondingly greater.

The consumption of fuel has been found to be, under ordinary working conditions during the rainy season, from $\frac{3}{7}$ lb. to $\frac{4}{7}$ lb. of wood consumed in the air heater, or stove, to every pound of tea turned out by the drying machine.

The same firm also build an automatic up-draught tea dryer, working on the same principle, and practically similar in construction to that just described, but which is of smaller capacity, and which being moreover mounted on the top of a double ended air heater, or stove, effects a considerable saving in the amount of ground space occupied.

This stove is fitted with two sets of tubes by which the air can be taken from either end. The weight of the drying machine is carried upon the side girders of the stove, which are so arranged as to be entirely independent of the brickwork, so that the stove and fireplace or furnace can, if desired, be repaired and rebuilt without in any way disturbing the drier above.

The main fast and loose pulleys of this machine are ten inches in diameter, and of a face surface suitable for a belt three inches in width, the proper speed of running being about 400 revolutions per minute. About 1 h.p. is required for driving.

The capacity of this drying machine is said to be two and a-half maunds (200 lbs.) of perfectly or fully fired (pucca) tea per hour.

A large number of improvements in tea drying and firing machines have been made by William Jackson, and his machines are well known and in successful operation.

In one of these machines a series of frames is placed one above the other in the drying chamber, each frame being fitted with perforated narrow shelves attached to rods which are free to turn in bearings in the frame so as to admit of their being tilted under the action of a spring connected to a rod journalled to crank arms or levers fixed upon the rods carrying the tilting shelves. Normally, this rod is secured by a catch, but upon its being released from the latter it will be so acted upon by the spring as to move or draw down the shelves through an angle of about 90°, and thus insure the tea leaf being discharged upon the shelf immediately below.

Another plan consists of straight rods fixed in frames forming two gratings, one of which moves horizontally above or below the other. In this case the tea leaf will fall through the spaces between the rods, the grating being kept in either position by a bolt entering recesses in the frame.

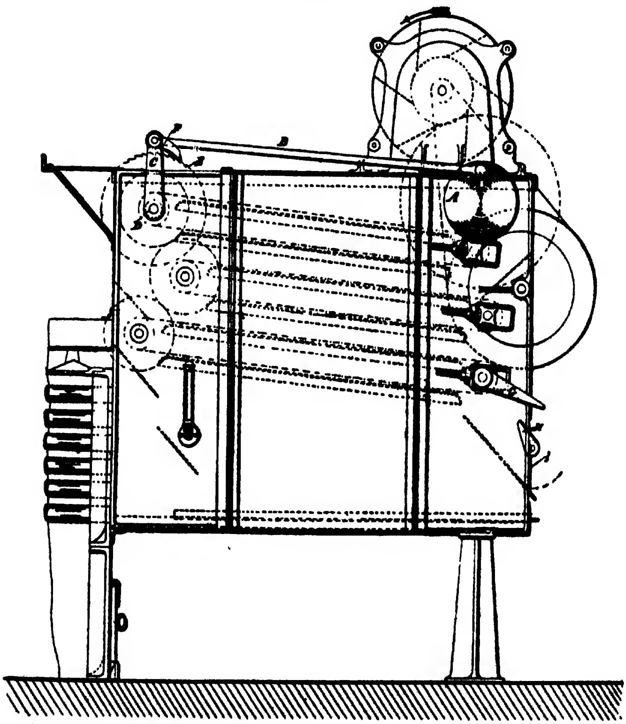


FIG. 90.—Automatic Up-draught Tea Drying Machine with Intermittently Moving Bands or Webs (side elevation).

A third method differs from that just described, in that the movable rods are bent at each end, supported in bearings in the frame, and attached to a sliding rod by which they can be turned partially round so as to leave the other grating open. The stationary rods are also slightly cranked.

One of Jackson's pattern of up-draught drying machines is illustrated in Figs. 90 to 93.

This drying machine is an improvement upon drying machines or apparatus of that class in which the tea leaf is carried through the drying chamber upon travelling webs or endless bands or carriers of perforated metal, and the objects of the improvements are to enable the leaf to be spread more evenly and properly upon the webs, bands, or carriers, and to insure the subsequent proper discharge of the dried leaf.

To effect the first of the above objects an intermittent motion is imparted to the webs, bands, or carriers, in such a manner that at the requisite intervals portions of the upper or top band, web, or carrier, will be presented before the charging inlet and remain there for a time to admit of charging and spreading the leaf, after which the webs, bands, or carriers, are moved on, and the following portion of the top web, band, or carrier, will be exposed to have the leaf placed and spread thereon, and so on *ad infinitum*.

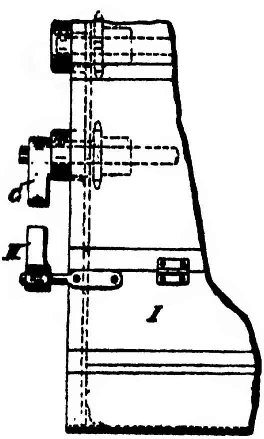


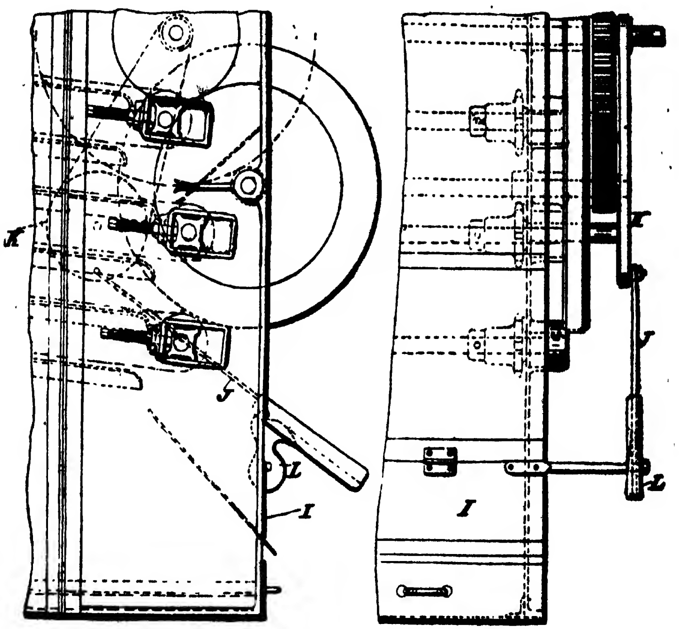
FIG. 91.—Automatic Up-Draught Tea Drying Machine with Intermittently Moving Bands or Webs (detail view of discharge door).

This intermittent movement is effected by various arrangements of mechanism—for instance, by arms on the axis of one of the pulleys over which the webs, bands, or carriers, pass, with which arms a projection on a wheel is arranged to come into contact at intervals; or by deriving a slow or reduced speed from the fan or other convenient rotating part of the apparatus, and connecting to the axis of the slow speed wheel a slotted crank-arm, crank-disc, or eccentric, or some equivalent device.

The latter arrangement is that employed in the machine illustrated, in which A is a crank disc to which is connected one end of a rod B, the other end of which rod is attached to a lever C, centred at D on the axis of a ratchet wheel E, and carrying a pawl F, engaging with the above ratchet wheel, which is fixed on the axis of one of the pulleys of the webs, bands, or carriers, so

that this pawl F will alternately move the webs, bands, or carriers, either through the usual gearing, or the top web, band, or carrier only, in the desired intermittent manner.

The proper discharge of the dry leaf or tea is effected by attaching to the axis of the pulley of the web, band, or carrier, in close proximity to the discharge, a device consisting of a



FIGS. 92 and 93.—Automatic Up-draught Tea Drying Machine with Intermittently Moving Bands or Webs (detail views showing modified form of discharge door).

knocker G, which at intervals will act on a lever H, attached to the discharge door I, as shown in Figs. 90 and 91, so that this door will be opened and the tea discharged, the door being kept closed in the intervals by counter-weights.

In the arrangement for effecting the intermittent opening of the discharge door, Figs. 92 and 93, a weighted and toothed rod J, is centred to a crank pin on a pulley disc K. On the door I

is fixed a piece L, having a resting surface for the weight, and provided with a tooth or projection, which, as the pulley disc K revolves, will be engaged and released at intervals by the tooth on the rod, so that the piece L, and consequently the discharge door, will be drawn over, and the discharge outlet opened, the piece L being then subsequently released so as to allow the door to fall back and to again close the discharge outlet.

Six later patterns of tea drying machines designed by the same gentleman comprise, briefly, the following novel features:—

In the first, the tea is passed on trays suspended on endless travelling chains through the drying chamber, through which hot air is drawn by an exhaust fan. The trays are tipped to discharge their contents, as they leave the drying chamber, by a stop acting upon tangs or cams, and the motion of the driving chains is rendered intermittent by a driving pawl operated by levers from a crank disc.

The second machine comprises an arrangement for adjusting the tension of the trays when they become extended through use, which is applicable to that class of machine in which endless chains of pivoted trays are arranged one above another in a drying chamber, the tea falling from one series of trays to another in succession until the lowest is reached and the tea is discharged.

This is effected by means of sprocket wheels and rollers at one end of the chamber, having their bearings mounted in slides and adapted to be moved as required by adjusting screws. To prevent the rollers being moved too far from the supporting rails during the adjustment, the latter are provided with extensions which take into grooves cut in the rollers.

The trays are provided along one edge with tubes, the ends of which form bearings for the ears of the carrying chains.

The feeding hopper is mounted on a rocking shaft, operated by a crank and eccentric.

The third has a drying chamber provided with travelling webs for supporting the charge, and supplied with air heated by hot gases from the furnace, which are arranged to circulate round tubes through which the air passes. These tubes are arranged in sets opening into chambers, or compartments, communicating with the drying chamber. Similarly constructed chambers are

likewise formed in the roof of the furnace, which chambers also supply hot air to the drying chamber.

The fourth is provided with two chambers, each of which is divided into compartments containing trays for the tea. Over each of these compartments is arranged a series of louvres, the pivot pins of which are connected together by links so that they may be opened or closed simultaneously, whilst the passages from the chambers to the fan are controlled by valves.

The fan is arranged to draw hot air from a tubular or other furnace through the different compartments.

The fifth is fitted with a discharging apparatus in which slots of equal length, in the bottom of the drying chamber and of the receiver respectively, are so arranged that, when they are caused to correspond, tea will be discharged from the dryer into the receiver, and that when the slot in the receiver is turned downwards to empty the latter, the surface of the cylindrical receiver will close the slot in the chamber bottom, and will prevent the entrance of cold air or external air into the drying chamber. The cylindrical receiver is wholly or partially rotated by means of a chain and pulley, or by a lever, toothed quadrant, and pinion.

And finally the sixth has a series of trays pivoted at one edge to a pair of chains carried by sprocket wheels. These trays are supported horizontally till they reach breaks or gaps. by rails, when they fall into a vertical position, their contents being discharged on the row of travelling trays below. A combination of several such sets of rollers and chains admits of the operations being repeated.

To prevent the tea from falling in ridges or heaps on the trays below, a cranked roller having a vibratory motion, or a roller having a rotary motion, is interposed in the path of the falling tea, so as to distribute it in a more uniform manner, these rollers being either circular, fluted, or of any other suitable shape.

Many different patterns of these drying machines are now built by Marshall, Sons & Company, Ltd., Gainsborough, amongst which mention may be made of the following:—

That which is known by the name of the "Victoria," which machine has been in successful use for some time, being a great favourite amongst planters by reason of its thorough reliability,

although it is somewhat slower in working than some of the other patterns.

The drying is effected in this machine by the leaf being automatically fed by mechanical means in a continuous manner on to endless metallic perforated travelling webs or bands, located the one above the other, by which webs or bands the leaf is carried through the drying chamber, and is finally automatically delivered or discharged at the opposite end of the machine from that at which it is fed in.

The mechanical feeder is situated on the top of the machine, the leaves being charged into it by an attendant standing on a shelf or foot-plate, and they are automatically scattered by it on to the uppermost web; but if desired the distribution of the leaves on the webs can be made by hand, notwithstanding the presence of the mechanical feeding arrangement.

There are five of the above-mentioned slowly-moving bands or webs mounted in the machine, their rotation being effected by a train of gearing. The leaves are quietly but effectually turned over the ends of these bands or webs four times during the progress of the drying operation. The speed of drying can be altered to any one of five different rates of time, ranging from nine to twenty-five minutes.

The exhaust fan is located on the top of the machine, and at the rear or discharge end of it, and draws the air upwards through the leaf. It is built of steel, and is of such a design and construction as to insure an air current of high velocity being drawn through the leaf, this being aided by the large air ports which collect the moisture over a wide area of the drying surface. The pulleys are of ten inches diameter with four-and-a-half inches width of face, and the speed of rotation should be about 320 revolutions per minute. The power required for driving this machine would be about 1½ h.p.

The old pattern of air heater or stove formerly used in connection with this machine can be advantageously replaced by one of the improved modern types of air heaters or stoves constructed on the multitubular system, which are fitted with an improvement of considerable importance consisting in the employment of tubes so arranged as to require no flanges on their locking ends, so that they can be all inserted from the outside or furnace end,

instead of from the machine end as was previously the case. The crown of the furnace is constructed of ordinary fire-bricks secured by wrought-iron clamps.

The quantity of dry tea which this machine is capable of delivering per hour averages about three maunds (240 lbs.), but the capacity of the machine will of course be subject to variation in accordance with the condition of the leaf, the state of the atmosphere, and the degree of temperature used.

The drying or firing machine, known as the "Empress," is very similar in construction to that which has been just described, the principal differences being, first, that no mechanical feed mechanism is employed, the leaf being simply scattered by hand on to the upper web or band, which is arranged to project beyond the extremity of the machine to receive it; and, secondly, that the travelling bands or webs are arranged to turn over the leaf five times inside the drying chamber, instead of four times as before. The dried tea is discharged in this machine beneath the platform upon which the operator stands.

The speed of the fan should be in this case about 375 revolutions per minute, and about 2½ h.p. would be required for driving purposes.

The capacity of the machine is from 240 lbs. to 300 lbs. per hour under average conditions.

What is called the "Paragon" tea drying machine comprises several further modifications. In this machine there are eight travelling perforated bands or webs in the drying chamber, by which the leaf will be turned over seven times during its passage through the latter. The machine is provided with a mechanical feeder which is located over the front end of the machine, which position has been found to be a very convenient one for the purpose, and a platform for the operator or attendant to stand upon is provided over the discharge aperture.

The thickness of the feed can be regulated by a vibrating plate fitted with vertical adjustment, but whenever desired the leaf may be scattered by hand, on the slowly moving web or band, without any alteration having to be made to the mechanical feeding apparatus.

The length of time for which the leaf will remain exposed to the current of heated air can be varied from a minimum of

ten minutes to a maximum of twenty-five minutes, by changing the strap on to the different steps of the cone pulleys. The gearing for imparting the requisite slow motion to the shafts of the travelling webs or bands consists of a compact but strong arrangement of worm wheel and screw, every shaft carrying boss being bushed and the entire gearing being well protected.

To admit of the whole of the internal working parts being readily got at for examination or repairs, a large door lined with asbestos is fitted on each side and another on the top of the machine, the inner ends of the tubes in the air heater or stove being also accessible through the first-mentioned side doors.

The speed of the fan should be about 450 revolutions per minute, and 2½ h.p. will be required for driving purposes.

The capacity of this machine under average conditions has been found to be from three maunds (240 lbs.) to four maunds (320 lbs.) of dry tea per hour.

When it is not considered desirable that the complete firing or drying of the leaf be hurried, and consequently a slow desiccation is desired, this may be effected by closing down the inlets to the fan and setting the webs or bands to run or travel at their slowest speed.

The "Chota-Paragon" machine possesses several further novel features, amongst which the following are those of the most importance: the drying surfaces in the hot-air chamber are fitted with slow motion, and the chains carrying them are so arranged that they will be moved independently of each other, thus throwing upon each of these the strain of only one travelling web or band, and in this manner enabling it to run for years without any special attention. Five different speeds can be given to the travelling webs or bands, and the velocity of the air current is capable of being controlled so as to render it suitable for the drying of heavy and light teas.

The drying or hot-air chamber, it will be seen, is located upon the top of the air heater or stove, the hot air being admitted from the latter to the drying chamber along its two sides and at one end of it, thereby insuring a very uniform distribution of heat all over the drying surfaces, and a consequent increase in the drying effect and economy in fuel consumption. Moreover, this arrangement tends to force all the heat to pass up through

the drying chamber, thus still further adding to its economical working.

A considerable saving in floor space is also secured in this pattern machine by the superimposition of the drying chamber on the top of the air heater or stove.

The fan should be run at a speed of about 400 revolutions per minute, the driving pulleys being ten inches in diameter by three-and-a-half inches width of face.

The air heater, or stove, used in conjunction with this drying machine, differs from the previous pattern by the tubes being placed across or transversely to the stove and furnace bars. The first two vertical lines of tubes are pushed in and locked from one side of the stove, and the next two vertical lines from the opposite side, and so on, thus providing for half the air from the exterior passing in to be heated at one side of the air heater, or stove, and half of it from the other side of it, and for the uniformly heated air to be delivered along the two sides of the stove, no matter how the furnace bars may be covered with fuel.

The furnace tubes can all be withdrawn and replaced without any necessity for touching or dismantling any other portion of the machine, and they are all easily accessible for brushing or cleaning down at any time.

The consumption of dry wood fuel in this air heater or stove has been found to be about ¾ lb. to each pound of dry tea produced.

The machine known as the "Venetian" has a drying or hot-air chamber, built of steel sheeting and arranged with a feeding platform in front, thus admitting of the air heater and firing pit being placed beneath a staging or verandah, and affording easy access to the feeding platform from the main building, as well as allowing the feeder more room and freedom to deal with the leaf.

The tray tipping gear employed in this apparatus has been remodelled and strengthened, and is fitted with balanced discs which require less power to move them than was the case with the gear used in the older patterns of these machines.

The discharge of the dried or fired tea is effected by means of a half-moon or cut-away cylinder mounted at the bottom of the

drying chamber into which the dried tea drops, and when the latter has become full the discharge can be effected by rotating the cylinder, and thus letting the tea drop or fall out of it without admitting of any cold air from the exterior gaining access to the drying or hot-air chamber.

The working of the machine can be controlled readily from the feeding platform, the tea being both fed and discharged from it, and suitable doors are provided on each side of the chamber, and within easy reach of the attendant, so as to admit of the progress of the operation being readily inspected.

The fan, which does not differ materially from those used in the other drying machines, is fitted with a driving pulley eight inches in diameter by three inches width of face, and it should be run at a speed of about 450 revolutions per minute.

The power required to drive the machine will be about 1½ h.p.

The air heater, or stove, is fitted with tubes of the same dimensions as those used in the stoves of the "Paragon" machines. The roof of the combustion chamber or furnace of this air heater, or stove, is constructed with a new design of interlocking fire-bricks, but in other respects it is of the same type as the multi-tubular forms employed with the other machines, and which have a tube chamber with a strong massive cast-iron frame set on the floor level, with no brickwork above the ground line.

A great advantage possessed by this form of stove is that there are no baffle plates or bye-passes inside, thus greatly simplifying its construction.

To render the machine especially suitable for the final firing of the finest assorted teas, the perforated steel trays are covered on one side with fine gauze brass mesh wire, secured in place by clips or otherwise, and which wire gauze does not detract to any material extent from the value of the machine as a dryer of fermented leaf, whilst preventing dust or fine tea from passing through, and rendering it especially suitable for use as an auxiliary dryer in large factories, and for the final firing of small or light teas, or finishing teas, which have been 75 per cent. dried in larger machines.

The capacity of a machine of the size shown, viz., 72 inches, is from 100 to 160 pounds of tea dried from fermented leaf in accordance with the condition of the leaf, weather, and temperature

used, these conditions also affecting the output when used for final firing. In actual work one of these machines has turned out 140 pounds of dry fired tea per hour, with a consumption of ¾ lb. of wood per pound of tea, the average temperature employed being 235° F., and the speed of the fan 510 revolutions per minute. The time occupied in drying the leaf in the drying chamber averaged eighteen minutes.

The capacity of the 42-inch machine varies from 50 to 70 pounds per hour in India, and from 80 to 90 pounds per hour in Ceylon.

A number of up-draught tea drying machines have also been devised by A. H. B. Sharpe.

One of these machines has a hopper containing an adjustable plate to which a rocking or kicking motion is imparted by its connection with the fan shaft. Within the drying chamber is mounted on the boss of a shaft a series of trays, each consisting of a number of radiating segmental flaps of perforated metal or woven wire, connected by hinges with a circumferential ring and the above-mentioned boss. The rings are connected with the boss by stays, ending in rollers which run on flat rings fixed to brackets, which latter also support inner rings and are fixed to the drying chamber.

The flaps are supported in a horizontal position by rings, except at one part of the circuit where the rings are cut away so as to allow the flaps to fall consecutively, and discharge the tea upon the tray below. From the last tray the tea is discharged into any suitable receptacle.

The shaft is driven by a worm-wheel and worm, or other suitable gearing connected with hand-wheels or other driving apparatus.

In a modification of this machine the drying chamber is placed upon the dome of a steam-boiler, and the air, which is drawn through the trays by an exhaust fan, is heated by means of the tubes.

In other forms of the apparatus the air is heated by vertical or horizontal tubes in a furnace, or by any other device in which the air does not come in contact with the products of combustion.

Two or more shafts can, if desired, be mounted in one chamber, and the trays may be formed of concentric rows of flaps.

In another type of machine the tea is fed from a hopper to a series of perforated trays carried by endless travelling bands, and is transferred automatically from one series to another.

The drying chamber is divided by partitions so as to guide the air from a multitubular air-heating apparatus to an exhaust fan.

A third pattern of machine comprises a series of endless trays, each constructed in reversible sections pivotally connected with carrying chains, and mounted on wheels on two revolving shafts, the trays moving in alternately opposite directions.

The tea is fed into the drying chamber through a hopper, and is carried along to the other end of it, where the tray sections swing on their pivots, and so drop the partially dried tea on to the next endless tray, which returns it to the left-hand end and drops it, and so on until it is finally discharged.

The tray sections are held up, until required to tilt, by rails acting on projections on the sections. The latter and the hopper and outlet are fitted with central ridges or partitions, so that the tea can be passed first through the cooler side of the machine, and then through the other, the heated air being preferably delivered from pipes, and drawn over the top course of trays by a fan.

Rotary brushes are provided for clearing the trays of leaves, and the various moving parts are driven by belt gearing, pulleys, &c., from the fan shaft.

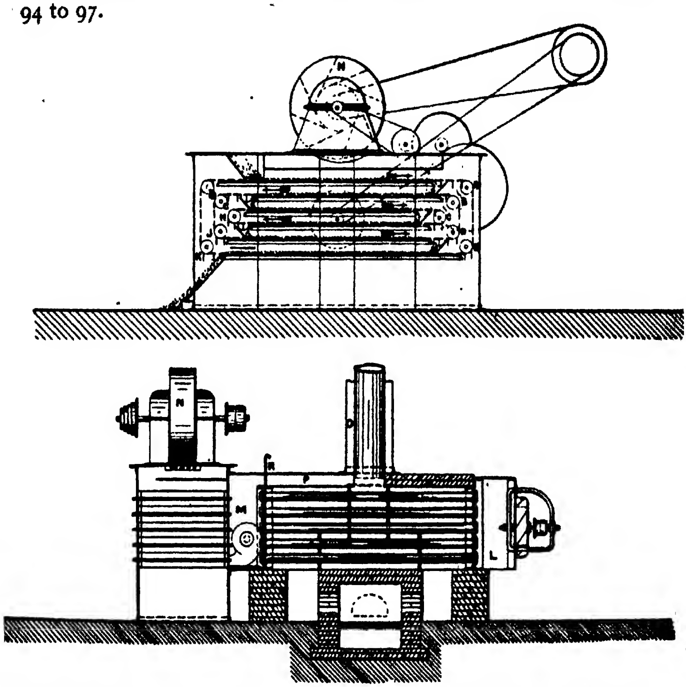
In a subsequent improvement upon this machine, instead of the wheels at each end of the machine, for carrying the series of endless trays, being mounted upon a common axis, each endless series of trays is carried by wheels mounted upon separate axles, the chains of trays being driven in such a manner that alternate horizontal sections move in opposite directions, and the tea fed into the apparatus travelling from one to another in succession until it escapes therefrom.

The axles of the carrying wheels are adjustable, and brushes are provided for cleaning the trays.

In addition to a fan located at the upper part of the apparatus for drawing a current of air from the air-heater through the drying chamber, an auxiliary fan is also arranged at the inlet end of the air-heating apparatus, or between the air-heating apparatus and the drying chamber, and a bye-pass is provided, by means of which, when the drying operation is required to be temporarily

stopped, the air forced through the heating apparatus may be passed direct to the chimney without going through the drying chamber.

The construction of this latter machine is shown in Figs. 94 to 97.



FIGS. 94 and 95.—Automatic Up-draught Tea Drying Machine with Reversible Oppositely Moving Trays (longitudinal and transverse sections).

In the two patterns of machines shown, the tea dryer will be seen to contain a series of endless tea-carrying trays each constructed in reversible perforated sections, pivotally connected at their ends to carrying chains supported on a series of actuating chain wheels, the latter being mounted on carrying and actuating shafts arranged at the opposite ends of the machine, so that the whole series of these chain wheels and endless trays are carried by such shafts, and will be operated therefrom in alternately reverse

directions, the adjacent courses of the series of trays being caused to traverse the length of the drying chamber in such alternately reverse directions, and at the ends of each traverse every course of such trays being caused to deposit its contents on to the relatively next lower course, by which action the tea will be carried back at a lower level to the other end of the drying chamber, and so on, the operation being rendered continuous until the dried leaves are finally discharged from the apparatus by the lowest course of trays.

In Figs. 94 and 95, A and C represent the chain wheels, which are so arranged as to give motion to the alternate chains and endless trays; for example, to the first and third of a series of three in the same direction, as shown by the arrows in Fig. 94. The chain wheel, B, gives motion to the remaining chains and endless trays of the series.

In the machine illustrated, there are but three of such endless trays with their supporting and actuating chain wheels, but it may be fitted with a greater number.

The chain wheels A, B, and C are keyed to their respective shafts, so as to impart motion to the first, second, and third endless trays, which latter are merely carried at one end by corresponding chain wheels D and E, which are loosely mounted on their axles, and at the other end by corresponding chain wheels F, G, H, J, and K, which are also loosely mounted on their axles.

The machine is shown in Fig. 95, in transverse sectional elevation, attached to a multitubular air-heating stove, at the opposite end of which, and forming a cold-air inlet, is fixed a casing or chamber L, fitted with a fan, which takes its supply of air from the surrounding atmosphere, and gently blows the air, which becomes heated on its passage through the tubes of this air-heating stove, into the drying machine.

In order to effect an economy of space, the fan in some patterns of machines is placed inside the hot air chamber M, and is arranged to gently draw the heated air through the tubes of the air-heating stove, at the same time blowing a continuous stream of pure hot air into the machine. The moisture from the drying tea is drawn off by an exhaust fan N.

Round the lower part of the air-heater chimney is provided a casing O, which forms part of a duct P, connected to the machine.

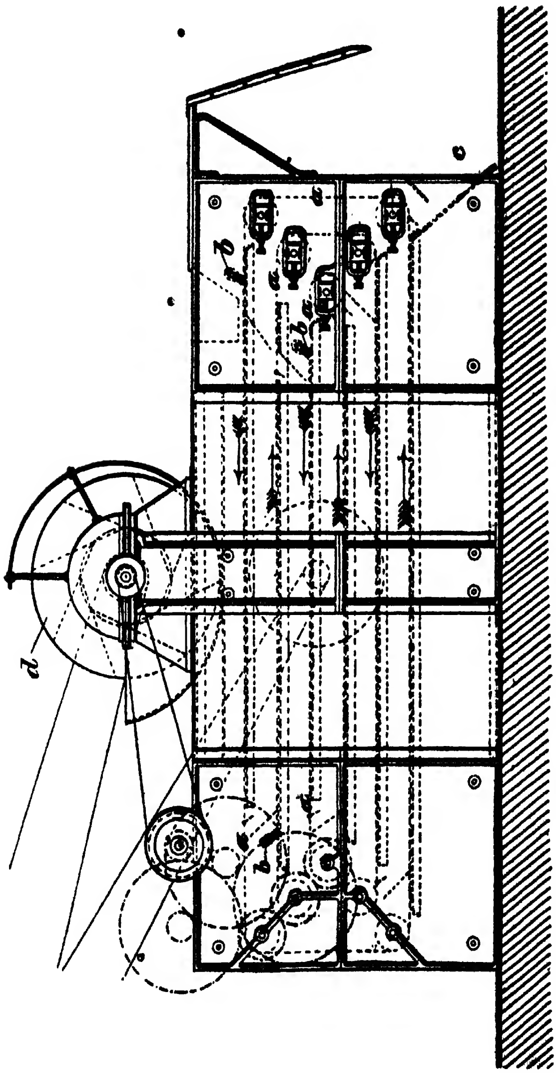


FIG. 96.—Automatic Up-draught Tea Drying Machine, with Reversible Oppositely Moving Trays Mounted on Separate Chain Wheels (longitudinal section).

In this duct is fitted a valve R, which is kept closed whilst the

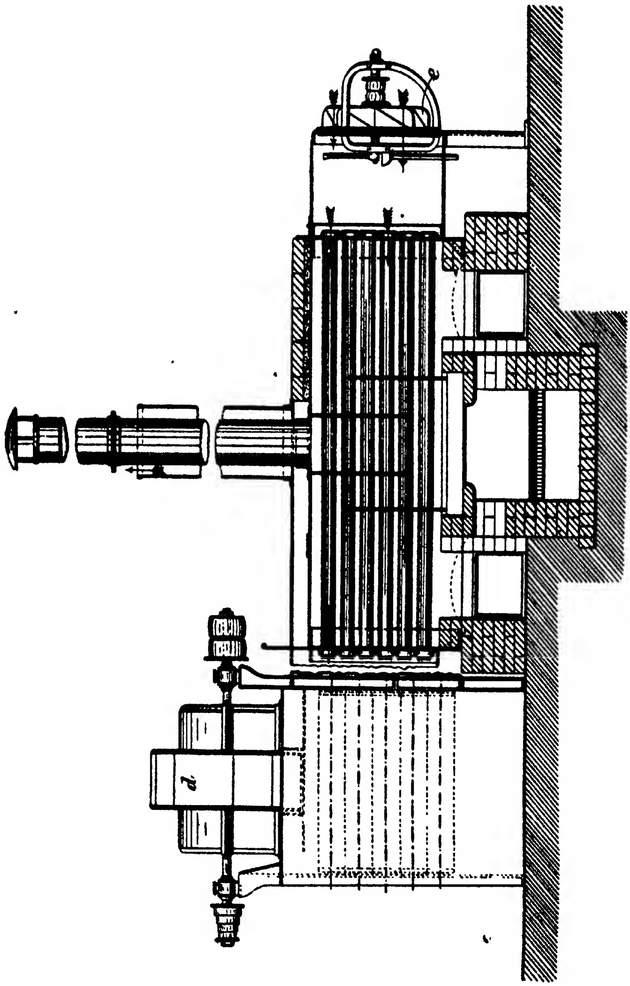


Fig. 97.—Automatic Up-draught Tea Drying Machine, with Reversible Oppositely Moving Trays Mounted on Separate Chain Wheels (transverse section).

machine is working; but in the event of any circumstance necessitating a temporary stoppage whilst the machine is full of drying

tea, the valve R can be withdrawn, and the hot air allowed to escape through the duct P, and casing O, so as to thus reduce the temperature in the drying chamber to such a degree as to avoid all risk of burning the tea.

In the drying machine shown in Figs. 96 and 97, each of the trays *a* is mounted at each end on a separate chain wheel or wheels, the wheels of each chain being mounted on separate shafts.

The series of wheels forming the driving wheels are keyed fast on their respective shafts, whilst those forming the carrying wheels are loosely mounted on their shafts, and adjustable bearings are provided for permitting the endless trays to be readily shipped and unshipped and adjusted as regards tension.

The shafts are driven in a manner substantially similar to that described with reference to the machine previously mentioned, and the arrangement will be readily understood from Fig. 96, without necessitating an extended explanation.

Stationary brushes *b* are provided for clearing the trays of such leaves as may tend to stick in their perforations.

The tea is inserted into the machine through the feeding hopper, and passes out or is delivered from the machine through the discharge outlet *c*.

A fan *d*, situated at the top of the tea drying chamber, draws atmospheric air into and through the air-heater, and into and through the drying chamber; whilst a fan *e* withdraws air from the atmosphere and gently blows the same through the air-heating tubes and into the drying machine, through which latter it circulates until it emerges on being withdrawn therefrom by the fan *d*. This arrangement is clearly shown in Fig. 97.

In a tea drying machine designed by N. W. H. Sharpe, the tea is placed upon alternately inclined trays in an inclosed chamber, these drying trays having bottoms perforated and transversely corrugated, and being pivoted at their upper ends and supported upon rods in such a way that, on the latter receiving a vertical reciprocating movement, the trays will be correspondingly actuated.

For this purpose they are hung at their lower ends upon cranks, the shafts of which are arranged to project through the drying chamber, and are carried in bearings capable of adjustment.

The tea-leaf is passed or fed through an aperture at one side of the chamber, and is carried through the latter from tray to tray by the rocking vibratory movement of the trays until the discharge outlet is reached.

A fan is arranged to draw heated air through the chamber from a tubular air-heater situated above a furnace, and around the tubes of which heater a series of baffles are provided to force the furnace gases to assume a circuitous path before reaching the chimney.

The following are brief descriptions of a few amongst the numerous other up-draught automatic tea drying machines that have been devised :—

That of J. A. Main comprises a series of superposed trays linked together so as to form an articulated framework. This framework being suspended from the roof of the drying chamber upon standards, so as to lie horizontally or to be capable of being tilted to any desired inclination, or being otherwise agitated to cause the tea to pass through it, and fitted internally with a fixed or an adjustable grid, in the latter case alternate bars of the grid being provided with pins which engage in slots in the ends of the hopper, and being secured in position by pinching screws, &c.

The apparatus for drying tea designed by M. Blake has a drying chamber traversed by bars of a Λ-section, the ends of which project through plates into boxes, the bars in the several rows being staggered, and the plates being secured to the side walls.

In the lower portion of the drying chamber are a number of conical troughs communicating with two compartments, from which pipes or conduits lead the tea into a trough, from which it is raised by a chain of buckets and discharged into the drying chamber until the latter is full. The valves are then opened, and heated air is admitted through the conduits or passages formed by the bars to the outlet pipe, a portion of the air escaping from under the bars and passing up through the tea. The dried tea can be removed by means of an elevator and a chute.

The air-heating furnace consists of a chamber into which the air to be heated is blown through a pipe at one end, and after circulating round the heating tubes through which pass the furnace gases, escapes by a pipe at the opposite end of the chamber.

A tea drying machine devised by R. Reynolds comprises an

arrangement for feeding the tea by conveyers into a chamber traversed by two sets of ducts open below. Both of these sets of ducts are closed at one end, and one of them communicates with a hot or cold air supply chamber situated at one extremity of the apparatus, and the other with an exhaust chamber at the opposite end, the ducts being so formed that the material will not accumulate upon them. The air is drawn through the apparatus by a fan, and escapes round the edges of the air supply ducts, and is drawn from the apparatus through the ends of the exhaust ducts.

The delivery of the tea can be regulated by a reciprocating and slotted plate, and agitators are provided between the rows of ducts, or one of the latter is suspended so as to be used for that purpose.

In a tea drying machine designed by S. C. Davidson, the tea is contained in a vertical chamber having perforated sides, in one arrangement, and in another is carried upon perforated trays secured to travelling chains, and a mixture of heated air and products of combustion from a stove or furnace is forced through it. A hopper is provided for feeding the tea into the vertical drying chamber, which is separated by a perforated partition from another or side chamber, and is provided below with a discharging apparatus consisting of a plate suspended by spring straps and reciprocated horizontally by means of an eccentric on the working shaft, the delivery being regulated by a sliding door.

The stove or furnace employed for heating the air comprises a fire box surrounded by an air chamber having openings to the external air. When the fire is first lighted, or just after the introduction of fresh fuel, it can be arranged to communicate with a chimney; but as soon as the fire is burning brightly the communication with the chimney is closed, another damper opened, and the products of combustion and heated air are together forced by a fan into the side chamber, from whence they pass through the perforations into the drying chamber.

A machine contrived by J. E. Lyndall is fitted with superposed trays in a drying chamber, supplied with heated air from a furnace below, baffle plates being so arranged beneath the trays that any tea dropping from the latter will escape into receptacles located on the exterior of the drying chamber. The upper trays are provided with projecting plates or baffles to intercept some of the hot air

escaping round the sides of those below, those on the uppermost tray of all extending right up to the sides of the chamber.

The fire gases pass from the furnace through flues into side chambers, where they are mixed together, and thence pass through tubes to the chimney, the air for drying purposes being heated by passing over these tubes, and a baffle plate causing it to take a circuitous route. A setting of firebricks serves to protect the ends of the tubes.

A machine for drying tea devised by Hobson and Croft is provided with an arrangement in which air is admitted to a suitable flue, and is heated by passing it in contact with a flue in an opposite direction to that taken by the products of combustion from the furnace. The heated air is passed into the drying chamber at a point above the furnace.

This latter chamber is provided with angle iron guides for shelves or trays, and the guides nearest to the inlet opening carry adjustable deflectors to distribute the current of air to the different tiers of trays.

The up-take flue surrounds the furnace chimney, so as to increase the draught through the drying chamber.

In Haworth and Copeland's machine for drying tea, the air to be used for drying purposes is heated by passing it through iron pipes raised to a high temperature by the products of combustion from a furnace circulating on the outside of them.

In the drying chamber are arranged a series of endless bands of chains, so operated as to move horizontally in opposite directions. Each of these chain bands is arranged to project at one end for a certain length beyond the one above it. At the end of each chain there is an adjustable flexible flap, under which the tea is carried for the purpose of spreading the leaf uniformly, and the dried tea is finally discharged into a box at the bottom.

The heated air is passed from the heating chamber of the furnace into the bottom of the drying chamber.

Steam-heated Automatic Tea Drying Machines.

A number of tea drying machines have been devised wherein the heating medium employed is steam.

In a machine of this type contrived by A. S. L. Hulett, steam

is passed through a series of pipes arranged in a circle between end boxes, which are mounted in a slightly inclined position and in such a manner that they are free to rotate in suitable bearings. The pipes are surrounded, except for a short distance at the lower end, by a cylinder of wire gauze or other openwork material.

The tea is fed through a hopper and hood into the centre of the ring of steam pipes, and is dried by the heat of the latter and by the air circulating through the wire gauze cylinder, being finally delivered between the uncovered ends of the pipes into a convenient receptacle.

A machine of the same class designed by E. Robinson, is so arranged that the tea can be passed by means of a hopper and worm, or other feeding device, into a rotary cylinder containing a worm conveyer formed of openwork material, and stirring blades or agitators located near its centre and circumference respectively.

The dried tea escapes from the cylinder at the opposite end to the feed, and hot air is forced by a fan through a central tube provided with nozzles, the moist air escaping through suitable apertures.

Provision is made for the heating of the air by causing it to take a spiral course through one or more annular chambers containing Archimedean screw surfaces and traversed by tubes heated by steam.

Steam-heated Machines for Drying or Firing Tea in vacuo.

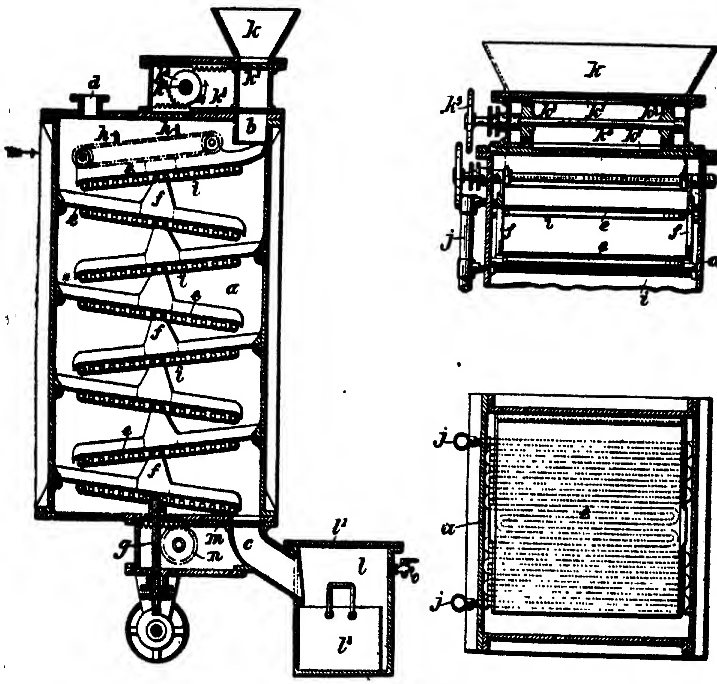
A machine for drying tea *in vacuo*, devised by W. A. Gibbs and G. W. Sutton,* comprises means for the introduction and removal of the tea, into and from the drying chamber, without destroying the vacuum, and so interfering with the drying operation.

In the drying chamber a series of shelves is so arranged that the material to be treated can be caused to pass from one shelf to another, in some instances pivoted inclined trays or shelves, shaken by suitable mechanism, being employed, and in others endless travelling trays or platforms. Beneath these shelves, and sometimes

* Built by The Blaxton Engineering Company, Limited, London.

also above them, are arranged coils through which steam can be caused to pass.

To admit of the tea being introduced into the drying chamber and removed from it when dried, inlet and discharge chambers are provided at its upper and lower ends respectively, these inlet



FIGS. 98, 99, and 100.—Automatic Steam-heated Vacuum Tea Drying Machine, with Pivoted Shelves or Trays (vertical and horizontal sections).

and discharge chambers having arranged in conjunction with them valves or closing devices, enabling communication between them and the drying chamber to be effected only when communication between the former chambers and the atmosphere has been cut off, and *vice versâ*.

In cases in which the continuous operation of the apparatus is not essential, the tea to be dried is placed upon a series of trays

which can be introduced into the drying chamber between heating coils, openings being formed in the wall of the said chamber for allowing of the introduction and removal of these trays, and the openings being closed by independent covers which rest against inclined seats in such a manner that the weight of the covers themselves will assist in maintaining tight joints for preventing the admission of air.

Figs. 98 to 100 show a tea drying machine of the above description fitted with pivoted shelves or trays, and Figs. 101 to 103 illustrate an apparatus of the same type fitted with sliding shelves, trays, or platforms.

Referring to the first pattern of machine, *a* is the drying chamber, *b* is the inlet, and *c* is the outlet for the discharge of the tea when dried. *d* is a flanged opening for connection with the vacuum producing apparatus. *e* are the inclined shelves or trays, all of which, with the exception of the uppermost shelf, being pivoted, and which are knocked or shaken in order to cause the tea lying upon them to gravitate from one shelf to the other through the entire apparatus.

Each of the shelves or trays, moreover, except the uppermost one, is provided with extensions *f*, upon which the superposed shelf is supported; and beneath the lowermost shelf is a rod *g*, operated by a snail or cam so shaped that at each revolution the entire set of shelves will be raised and then suddenly allowed to drop.

Two bars or stirrers *h*, carried by sprocket chains running over sprocket wheels on two shafts—the former of which is carried in bearings upon the shelf, whilst the latter serves as a pivot upon which the upper shelf oscillates, and which extends through a stuffing box in the side of the chamber and is provided on its outer end with a hand wheel—are provided for discharging the tea from the uppermost rocking shelf or tray, if it should be found necessary to do so owing to any tendency to stick.

Steam heating coils *i* are arranged beneath each of the shelves or trays, the several coils being connected with common flow and return pipes *j*, as clearly shown in Fig. 100.

To prevent the vacuum from being destroyed when any tea passes from the hopper, which is shown at the upper part of the apparatus, into the drying chamber, the hopper is fitted with two

slide valves k^1, k^2, which are opened and closed by a pair of racks operated by mutilated pinions k^3, mounted on a shaft k^4, carrying a hand wheel k^5, which, when turned in the direction of the arrow, Fig. 98, will first close the valve k^2, and then open the valve k^1, so that any tea that may be lying upon the latter will fall on to the valve k^2. Upon rotating the mutilated pinions in the reverse direction, the valve k^1 will be first closed, and the valve k^2 afterwards opened, so that the material lying upon it will fall on to the uppermost tray or shelf in the drying chamber, whence it gravitates along the several trays or shelves to the discharge outlet *c*, from which it passes into a chamber *l*, provided with an air-tight cover l^1, and containing a receptacle l^2, into which the dried tea will fall.

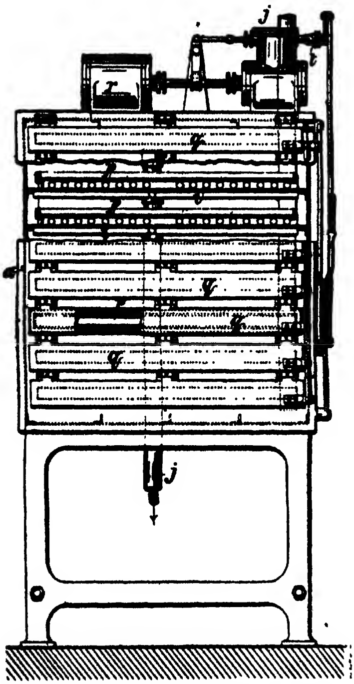


FIG. 101.—Steam-heated Vacuum Tea Drying Machine, with Sliding Shelves or Trays (sectional front elevation).

For closing the communication between the drying chamber *a*, and the dried tea receiving chamber *l*, during the time that the receptacle containing the tea is being removed, a slide valve *m*, operated by a pinion *n*, is provided.

A cock *o* allows of air being admitted to the chamber *l* before the removal of the cover l^1.

Figs. 101 to 103 illustrate the arrangement of removable trays *p*, which slide on suitable guides above heating coils *i*, the latter being placed as indicated in dotted lines in Fig. 103. *j* is the steam supply pipe.

Doors *q* are provided for permitting of the introduction and

removal of the trays p into and from the drying chamber, these doors being so pivoted as to lie against inclined seats formed around the openings, through which the trays p are introduced. In each seat a packing ring is arranged around the opening, against which the doors q will lie, so as to form a tight joint.

In order to enable all the doors q to be opened and closed simultaneously, they are each provided with a pin inserted in a hole in a common rod connected to one arm of a bell crank lever, the other arm of which is coupled by a link to a hand lever in such a manner that when the latter is moved the doors will be operated.

The air-exhausting pump r is arranged, in the pattern of machine illustrated, upon the top of the drying chamber.

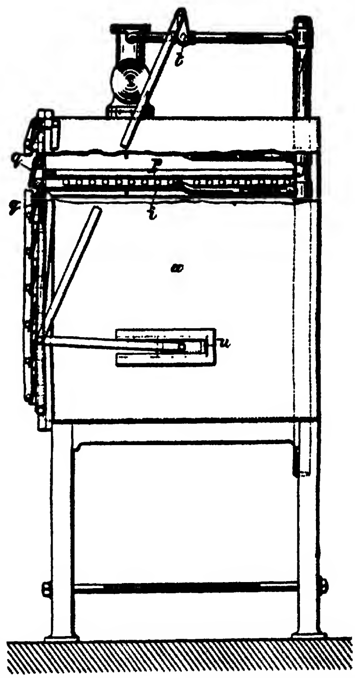


FIG. 102.—Steam-heated Vacuum Tea Drying Machine, with Sliding Shelves or Trays (sectional side elevation).

By connecting the cock or valve t for regulating the admission of steam to the steam cylinder for working the exhausting pump, with the door operating lever, when this lever is moved to open the doors q the cock or valve t will be operated to shut off the steam and stop the pump; another valve u, also connected with the same lever, serves to admit air into the chamber, and thus destroys the vacuum in it, so as to permit of opening the doors q, the arrangement being such as to admit of a certain amount of movement being imparted to this air valve before the doors commence to open.

A recent pattern of machine of this type, patented by G. W. Sutton, and constructed by the Blaxton Engineering Co., Limited, London, is shown in Fig. 104. An important advantage possessed by the system is that the temperature is completely under control at any point during the drying or firing process. The passing of

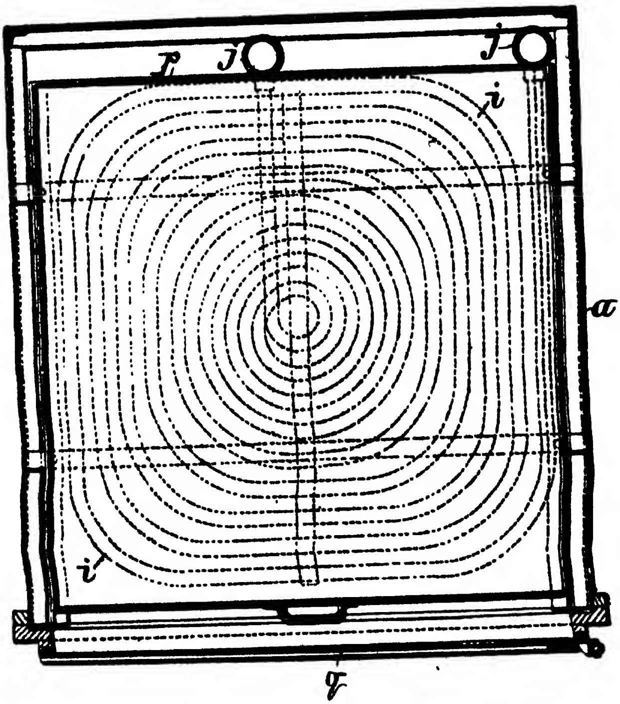


FIG. 103.—Steam-heated Vacuum Tea Drying Machine, with Sliding Shelves or Trays (horizontal section).

the leaf, moreover, over steam coils at a high temperature insures an instantaneous stoppage of oxidation, the drying being continued at the same temperature until the leaf has become from 50 to 75 per cent. dried. Having attained this stage of desiccation, ...on to trays located over coils at a lower tempera... ...acting to drive off the remaining moisture,

retain the essential oils, and, it is averred, give to the completely dried tea a distinctly brisk and malty flavour; and this finishing off at a low temperature, besides tending greatly to retain the good qualities of the leaf, is also said to considerably improve its keeping qualities.

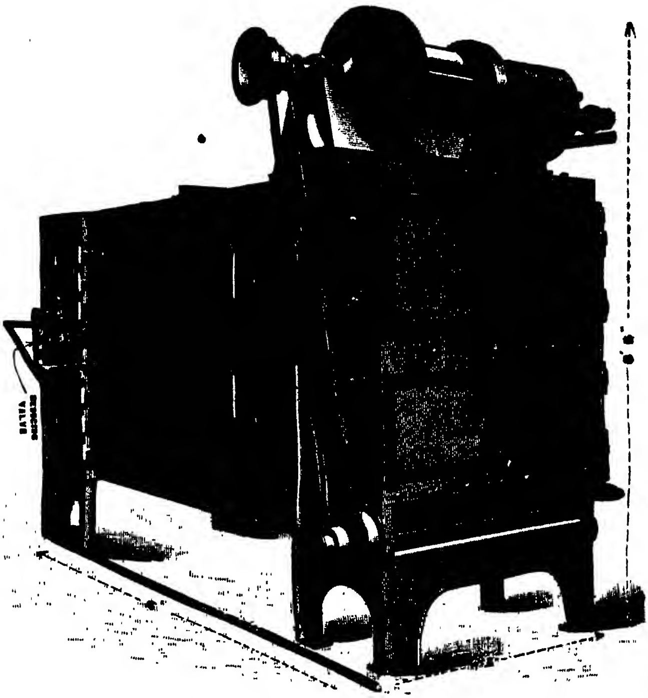


FIG. 104.—Recent Pattern of Automatic Steam-heated Safety Tea Drying Machine (perspective view).

The machine requires no brickwork or foundations, and can be worked on an upper or lower floor without risk of fire.

The drying chamber is so constructed as to be capable of being packed for transport in two parts or halves weighing about 15 cwts. each, with trays, coils, and spreaders fitted complete, the

fan only requiring to be erected and the steam pipe connections to be made.

Standard machines of this type would occupy spaces of 15 ft. × 4 ft. 6 in. × 8 ft. 6 in., and 12 ft. × 3 ft. 6 in. × 9 ft.

If a small high pressure boiler be employed, and the fan be driven by a separate engine attached, the machine will be rendered independent of the shafting and of the main boiler and engine of the factory. The closer this boiler can be placed to the dryer the better naturally will be the results.

Under favourable conditions, this machine will dry about 300 lbs. of tea per hour, with an evaporation of some 300 lbs. of water in the coils. This is equal to a fuel consumption of about $\frac{1}{7}$ lb.* of coal to each pound of tea dried.

An apparatus for drying and firing tea planned by L. M. Torin, consists practically of a steam-heated vacuum pan fitted with an agitating or stirring arrangement.

Mr. A. Dyer's machine for drying tea *in vacuo* consists essentially of a divided cast-iron chamber surrounded by a jacket into which steam can be admitted.

This chamber is divided by a horizontal partition, which is fitted with a sliding door having bevelled edges covered with an elastic material to form an air-tight joint, and suitable closure devices are provided. Pipes governed by stopcocks or valves connect together these chambers, and the top chamber is provided with an inverted bell to prevent any tea from being carried off up the outlet pipe to the condenser.

On a main vertical shaft is carried a series of stirrers or agitators, which are so arranged as to be inclined at different angles to the shaft, and four of these arms are curved, and have vertical cutters fixed at different inclinations along their entire length.

The charge of tea can be inserted through a door into the chamber, which is fixed by a screw working through a bridge, and a semicircular worm wheel keyed to a shaft, having also suitable arms, through which the screws carrying the doors at the bottom of the chamber work. These arms, after being revolved by the above-mentioned semicircular worm wheel, will be held in their horizontal

* Assuming one pound of coal to be capable of evaporating 10 lbs. of water.

position by a sliding bolt, the screws being then employed to screw the doors up tightly.

The entire apparatus is supported on six columns, and a chute is provided to direct the charge of tea into any suitable receptacle after it has been properly dried.

CHAPTER IX.

MACHINES FOR THE NON-AUTOMATIC DRYING OR FIRING OF THE LEAF.

Non-Automatic Down-draught Drying or Firing Machines — Non-Automatic Up-draught Drying or Firing Machines—Non-Automatic Steam-heated Drying or Firing Machines.

In this type of drying and firing machine the leaf or tea is, as has been already mentioned in the previous chapter, completely under the control of the attendant during the entire duration of the drying or firing operation. This fact will obviously admit of the very delicate operation of final firing being effected to a nicety with these machines without incurring the danger of burning or smoking, to which the tea at this last stage of the process, when it is carried out in most automatic machines, in which the condition of the tea is not visible to the operator, must be liable.

As in the case of machines working automatically, those on the non-automatic principle may likewise be sub-divided into two main classes, viz., machines which operate on the down-draught, and machines operating on the up-draught principle.

Non-Automatic Down-Draught Drying Machines.

Commencing as before with machines working on the down-draught principle, a good example of which will be found in the machines invented by S. C. Davidson.[1]

One of these machines comprises chambers in which the tea is exposed upon trays, sieves, or other suitable carriers, to the action of heated air passing through them, apertures being provided to

[1] Manufactured by Davidson & Co., Ltd., Belfast.

allow some of the heated air to pass directly to the upper carriers without having to pass through the tea on the lower carriers.

In another machine either a very strong current of heated air, or of cool desiccated air, can be used for rapidly drying tea, placed on sieves or perforated trays arranged in a drying chamber, one above the other in a vertical column, and movable in successive order of rotation from the bottom to the top of the column, without the material being whirled by the strength of the current into heaps on the trays while in the drying chamber, or being blown away off them by it when the trays are being put into or taken out of the apparatus.

The apparatus consists, shortly, of a rectangular drying chamber, having an inlet port in the top end of it for admitting the heated or desiccated air, and an outlet or exhaust port for its exit at the lower end, the course of the air current being in this manner directed from the top to the bottom of the drying chamber. Between these inlet and outlet ports a column of superimposed sieves or perforated trays, on which the tea is placed, is arranged in the drying chamber, which trays are capable of being moved upwards, one after the other in successive rotation from the bottom to the top of the column, and therefore in a contrary direction to the course of the air current. These sieves or trays can be arranged on ledges inside the drying chamber like drawers placed one above the other, and each having an opening for itself in the side of the drying chamber, by which it can be inserted or withdrawn.

When the above arrangement of the trays is employed their movement in successive rotation from the bottom to the top of the column is effected by withdrawing the top tray, then moving the next below it into its place; afterwards putting the third tray in the place of the second tray, and so on to the bottom tray which, when drawn out from the lowest place, and put into the one above it, leaves the bottom space vacant into which a fresh tray can be then placed.

In another arrangement the drying chamber is so constructed that the trays can all be simultaneously moved up in a pile, one on top of the other, by a lift arrangement fitted in the base of the drying chamber, and operated by an arrangement of levers and vertically sliding bolts, motion being imparted to this mechanism

by a lever, operated either directly by the attendant in charge of the machine, or by so connecting it to the door of the tray-ports, that the shutting or opening of the door will raise or lower the lift.

Ports or doorways are provided in the drying chamber opposite the top and bottom trays of the column for admitting of the insertion of the bottom tray or withdrawal of the top one. When the bottom tray has been inserted, it is next raised by the lift to a sufficient height to allow another tray to slide freely in below it, in which position it will then be caught by four pawls, and held suspended when the lift is lowered down to its original or normal position. Another tray can now be passed in through the tray-port or doorway, and on the lift being again raised the new tray will push the previous one up in front of it, which latter will then be caught by the pawls in a similar manner to the first one, and will be held up by them with the upper tray resting on the top of it. This operation is then repeated until the top tray comes opposite the upper tray port, through which it can be withdrawn or removed as soon as the tea on it is found to be in a sufficiently dried condition. Both these tray-ports or doorways are fitted with doors which must be kept closed after inserting or withdrawing the trays, so as to prevent the passage of air through them into or from the drying chamber.

The current of air is produced or drawn down through the trays by means of an exhaust fan situated at the bottom, or by a blower placed at the top, of the apparatus, or by a powerful chimney draft connected to the outlet port.

The air is heated by an air-heating stove or furnace.

As the air current passes down through the trays from the top to the bottom of the drying chamber, it will be obvious that no matter how strong the current may be, it cannot disturb or blow the tea about on the trays so long as they are in their proper position within the drying chamber, for the stronger the current the more firmly will the tea be kept in its place on the trays.

During the time, however, when the trays are being inserted or withdrawn, there will be such a strong in-draft through the bottom tray-port, when the air current is being created by an exhaust from below the bottom tray, or out-draft through the

top tray-port when it is created by a pressure blast delivered above the top tray, that, unless the air current be checked during the time that the trays are being put into or taken out of the apparatus, the rush of air through the open tray-ports would be so strong inwards or outwards, as the case may be, as to cause the tea to be blown off the trays. In order, therefore, to effect a temporary modification of the air current, whether it be created by exhaust or pressure blast, the exhaust outlet or the pressure blast inlet, as the case may be, is fitted with an air valve, such as a louvre, or a gridiron valve, which may be either operated directly by an attendant, or by being so connected to the doors of the tray-ports that the opening of these doors will close the air valve, which will sufficiently modify, or, if necessary, practically stop the air-draft, so that during the time the trays are being put into or taken out of the apparatus, there will be little or no rush of air through the open tray-ports, and, consequently, no blowing away of the tea off the trays, and the shutting of these doors will open the valve again, and allow the full air draft to operate through the trays as before.

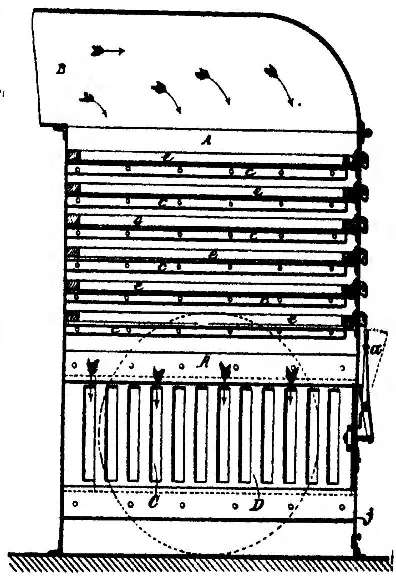


FIG. 105—Non-Automatic Down-draught Tea Drying Machine, with Sliding Trays (vertical longitudinal section).

A door provided between the top and bottom tray-ports facilitates the removal of all the trays from the drying chamber, by allowing of the removal of the intermediate trays between the top and bottom trays of the column.

Fig. 105 illustrates an apparatus fitted with perforated trays arranged to slide in and out like drawers, and with a gridiron valve for closing and opening the exhaust air-port below the trays.

Figs. 106 to 109 show drying machines in which the perforated trays or sieves can be elevated in a column from the bottom to the top of the apparatus by a lifting appliance fitted below the trays, and in which the air valve for closing the exhaust air port is so connected with this lifting appliance that the operation of the lift will open and close the air valve, and at the same time will close or open the door of the lower tray-port for the insertion of fresh trays.

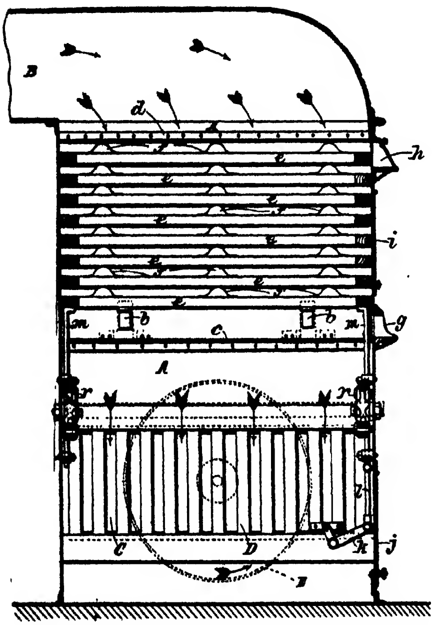


FIG. 106.—Non-Automatic Down-draught Tea Drying Machine, with Rising Trays (vertical longitudinal section).

The course and direction of the air current is shown in each figure of the drawings by arrows.

Referring to Fig. 105: A is the drying chamber; B is the inlet port for the heated or desiccated air; C is the outlet or exhaust air-port; D is a gridiron valve for controlling the passage of the air through the exhaust port; E is the exhaust fan; *a* is a lever operating the gridiron valve; *e* are the trays or sieves; *j* is a door admitting of access to the lower part of the drying chamber.

In Figs. 106 to 108 *b* are pawls for holding the trays suspended,

and which are constructed to drop in by their own weight below the trays when elevated by the lift clear of the pawls; *c* are angle-iron rails or slides for supporting the trays; *d* is an angle-iron stopper for preventing the trays from being lifted past the upper tray port; *e* are the perforated trays or sieves; *f* are the carriers on the top of the trays for supporting the trays above them; *g* is the lower tray port or inlet, and *h* is the upper tray port or inlet; *i* is a door for the removal when necessary of the

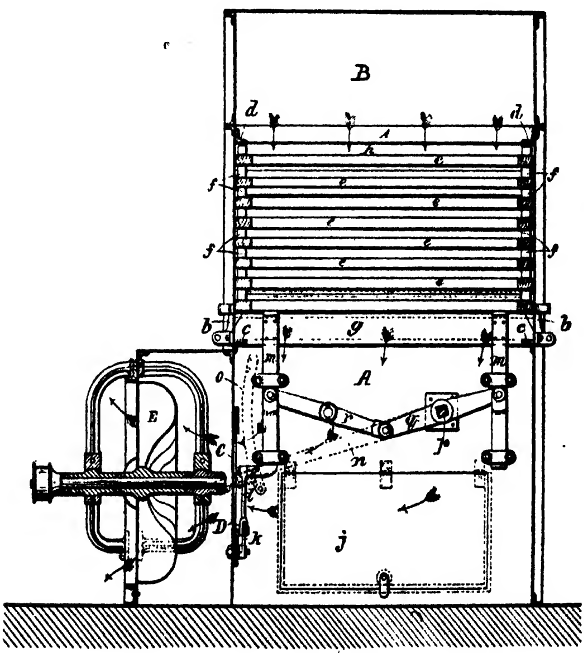


FIG. 107.—Non-Automatic Down-draught Tea Drying Machine, with Rising Trays (transverse section).

intermediate trays between the upper and lower tray ports; *j* is a door giving admission to the base of the drying chamber; *k* is a bell crank connection for operating the gridiron valve D of the exhaust air-port by the movement of the tray lift; *l* is a

connecting rod coupling the lower end of one of the tray-lifting bars *m* to the bell crank *k*; *n* is a lever operating a tray lift; *o* is the catch and a segment for holding the lever *n*, in the required positions; *p* is a spindle or shaft operated by the lever *n*; *q* is one of a pair of beam levers mounted on the spindle *p*, one end of which acts directly on the bars for lifting the trays, and the other end of which is connected to the beam lever *r*, which latter is connected to one of a pair of beam levers for operating the opposite pair of bars for lifting the trays; *s* (Fig. 108) is a door for the admission of cold air into the air-supply duct to reduce

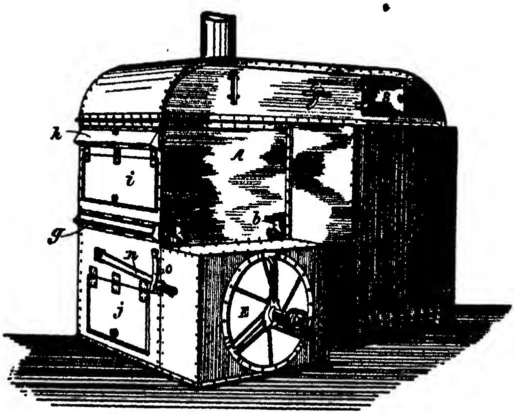


FIG. 108.—Non-Automatic Rising Tray Down-draught Tea Drying Machine, with Vertical Flue Air-Heater (perspective elevation).

the temperature of the air current when necessary; *t* is a throttle valve for cutting off the air supply; *u* is the air-heating stove.

A later pattern of this machine has columns of trays divided into two or more series supported independently by a separate set of pawls, so that the uppermost trays of the lower series may be removed without interfering with the trays of the series next above it. The heated or cooled and dried air is drawn or forced in a downward direction through the drying chamber, but the machine may be also constructed as an up-draught one.

In another arrangement the trays are caused to move downwards in a step by step fashion instead of upwards as usual.

In Davidson's latest pattern of down-draught machines, known as "Sirocco" tea dryers, which are made of both right and left-hand types, and are provided with cast-iron vertical flue air heaters or stoves, the leaf is exposed to the current of heated air upon wire-web trays constructed with a teak framework strongly bound together by diagonal stays; and, furthermore, strengthened and faced with metal-wearing surfaces. The number of trays taken in each of these machines consists of six in the smaller size and eight in the larger size.

The tray containing the wet leaf is first inserted into the drying chamber through the upper tray-port, where it receives the first contact of the fresh, hot air direct from the air-heater or stove, all further tendency of the leaf to ferment being thus instantaneously arrested. The tray should only remain in this position for the time occupied for each change of trays, that is to say, for about two minutes, after which the tray should be withdrawn from the upper tray-port, the leaf upon it lightly turned and shaken up, so as to impart to the finished tea a better twist or curl, and it should be next inserted into the lowermost tray-port, and passed from thence successively up through the column of trays to the central tray-port, on reaching which the tea, when fully dried and removed from the machine, will feel comparatively cool to the touch, which effect is due to the air, by which the drying operation was completed, having first traversed the layers of damper leaf on the trays above, and thus had its original temperature considerably reduced.

The result of this latter plan of working is that the complete finishing off, or the drying of the tea can be effected without any danger of burning or over-firing taking place.

This method of working is the reverse of that which was formerly adopted, which, as has been previously mentioned, was to first introduce the tray containing the wet leaf, which it was desired to dry, into the lower tray-port of the drying or hot-air chamber, in which position it would be acted upon by the air current, which had first to pass through the layers of leaf upon all the other trays which were already in the machine, and had been thereby correspondingly cooled. From this lowermost position the tray was then moved successively upwards through the column of trays until it reached the uppermost tray-port,

where the drying was completed under the action of the heated air arriving direct from the air-heater or stove.

It has been found, however, as the result of experience gained in practical working, that what is termed the inverted system, that is to say, the exposure of the wet rolled leaf on first entering the drying chamber to the fresher and hotter air, will produce the better qualities of tea. This result is claimed to be due to the instantaneous checking of fermentation which takes place, and which causes the tea to possess a greater briskness of liquor, and to the fact of its being in such an advanced state of desiccation when removed from the upper tray-port as to be stiffened up considerably, after which, on being shaken up, it will rest very loosely and openly upon the tray when introduced into the drying chamber at the bottom tray-port, and a superior twist or curl will be thus imparted to the tea.

The raising of the trays from the bottom of the drying chamber is effected by a strong and easily worked mechanical lift moved by a hand lever, the operation of which latter also acts to open the sliding door of the lower inlet tray-port, and simultaneously to close a throttle valve between the trays and the fan, and to lower the tray-lift to receive the inserted tray. After this a downward movement of the hand lever will raise the tray on to the supporting pawls, and at the same time effect the closing of the door of the inlet port, and the re-opening of the throttle valve between the fan and the trays, so that the fan will be again permitted to act on the trays with its full suction power, the regulation of which latter can be controlled by the size of the opening to which the damper valve is set on the exhaust pipe of the fan.

This arrangement of mechanical lift very effectually provides for the trays being inserted or withdrawn in calm air, and avoids any undue disturbance of the leaf.

The current of heated air employed may be of any desired temperature from 160° to 240° F. The regulation of the temperature being capable of being effected with great facility by a simple movement of the damper valve on the exhaust pipe from the fan, the action of which is to either diminish or increase the quantity of air drawn through the air heater, or stove, and thus in a few minutes to either raise or lower the heat as may be

required, for, as will be readily seen, the smaller the volume of air that is passing through the air heater or stove the higher will be its temperature, and *vice versâ*.

This action is rendered possible in machines of the down-draught type, owing to the principle upon which they work being such that, no matter what may be the strength of the air-current that is employed, the leaf will not be whirled about on the trays whilst they are in the drying chamber, nor blown off them whilst they are being inserted or withdrawn through the tray-ports.

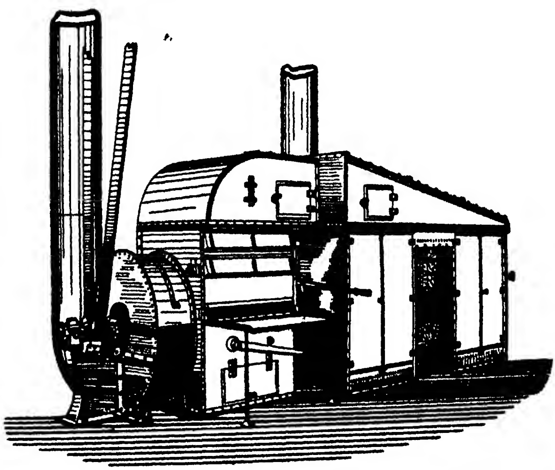


FIG. 109.—Non-Automatic Down-draught Tea Drying Machine, with Multitubular Air Heater, Right Hand Type (perspective elevation).

The entire apparatus, with the exception of the trays, is constructed of iron and steel, and it is entirely self-contained and complete in every detail, no brickwork or masonry whatever being required in the construction of the air-heater, or stove, and the entire apparatus being designed to work on the ground level.

Instead of being located at the side of the machine as shown in Fig. 108, the fan is placed at the end of the drying chamber, as shown in the case of the dryer fitted with the multitubular air-heater illustrated in Fig. 109.

The left-hand pattern machine is of precisely the same construction as that just described, except that the air-heater or stove is situated on the left-hand side.

When two down-draught machines are required to work close together in a tea factory, it would generally be found to be more convenient for stoking purposes to have one of them with the air-heater or stove on the right-hand, and the other with it on the left-hand side of the attendant in the drying chamber, an arrangement which, owing to the fire-doors of the air-heater or stove being situated opposite to each other, would admit of one man easily attending to the stoking of both machines.

These machines are, however, usually constructed with the air heater, or stove, situated on the right-hand, unless otherwise desired.

The approximate dimensions of the largest size machine, both right and left-hand type, are, length, 14 feet 5 inches; width, 7 feet 2 inches; and height, 7 feet 2 inches; and those of the smallest size machine, length, 13 feet; width, 6 feet 8 inches; and height, 6 feet 3 inches.

Fig. 109 shows a tea drying or firing machine of the right-hand type, and of similar construction to those which have been just described, but provided in this case with a multitubular air heater or stove of the same pattern as that illustrated in Figs. 85 to 88, only of somewhat smaller dimensions. This pattern machine is also made with the air heater or stove arranged on the left-hand side.

The machine (both left and right-hand type) is built in two sizes, the larger one being approximately 18 feet in length, by 9 feet 2 inches in width, by 7 feet 2 inches in height; and the smaller one being approximately 16 feet long, 8 feet wide, and 6 feet 3 inches high.

In Fig. 110 is shown an underside view and a side elevation of one of Davidson's improved make of trays, intended for use in the down-draught drying machines which have just been described. As has been already mentioned, the frames are made of teak, strengthened with steel corner plates. An improvement introduced in these trays consists, in the substitution for the wooden supporting bars hitherto employed along the right and left upper sides of the tray frames, of steel slide bars having countersunk

recesses to receive the heads of the bolts which pass through the frame at these parts, thus insuring both ends of all the bolts employed in these trays tightening against metallic surfaces, and causing the top and bottom plates to rigidly clasp the corners of the wooden frames between them, so as to thereby impart to the tray far more strength and stiffness, with but a very slight accession of weight. These plates likewise form efficient sliding surfaces for the tray, and prevent wear of the wooden frame.

Underneath the netting are arranged diagonal cross-stays, as shown in the drawing, and steel protecting plates are affixed to the frame at those sides which come directly opposite to, and are engaged with by the pawls and lifters, thus preventing unduly rapid wear of the tray frame at these points.

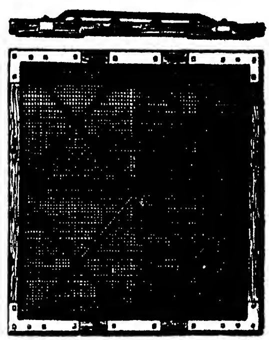


FIG. 110.—Tray for Non-Automatic Down-draught Tea Drying Machines (underside view and side elevation).

The wire web used for the tray is galvanised after being woven, which tends to considerably increase the strength and durability of the apparatus.

In a down-draught non-automatic machine adapted for drying tea, designed by J. Brown, air, heated in a special furnace, is drawn down by the draught of a chimney through the tea which is placed on horizontal trays in the drying chamber. These trays are pushed through in continuous series in at one side of the chamber, and out at the other, the sides of the drying chamber being formed so as to taper towards the bottom, and thus to collect any waste from the trays.

In another arrangement a fan or blower is substituted for the furnace draught.

NON-AUTOMATIC UP-DRAUGHT DRYING MACHINES.

As regards the tea drying or firing machines of the non-automatic class which are arranged to work upon the up-draught

principle, those shown in Figs. 111, 112, and 113, form typical examples.

These illustrations give a vertical section and perspective views of three patterns of machines of this kind, designed by S. C. Davidson, which machines are generically known under the name of "Siroccos," and which whilst being non-automatic so far as the manipulation of the tea is concerned, are what is known as self-acting, that is to say, the air current is an induced one, and not forced or drawn through the machine by a fan or blower.

This idea of utilizing the discharge of the waste products of combustion up a flue or chimney to induce an increased current through a drying chamber for tea leaf, was embodied in an apparatus devised by Davidson some twenty years ago.

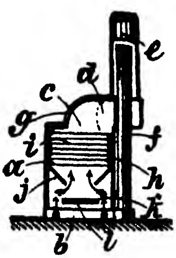


FIG. 111.—Four-Tray, Non-Automatic Up-draught Tea Drying Machine (vertical longitudinal section).

The original apparatus, which is shown in its simplest form in vertical central section in Fig. 111, is still in successful use. It consists of a drying chamber *a*, formed of a double casing of sheet-iron between which is placed non-conducting material, and which chamber is connected with a hot air flue *b*, supplied by an air-heating apparatus, and is also connected by an opening *c*, and flue *d*, with the chimney *e*, into which latter the air heating apparatus likewise discharges its smoke through the smaller internal chimney stack *f*, thereby causing an induced current of heated air to pass through the drying chamber *a*.

In the flue *d*, is located a damper *g*, which is arranged to normally close an aperture in the top of the flue, but which, when a strong draught is not required, can be swung round, as indicated in dotted lines in the drawing, so as to uncover the top opening, and close or cut off all communication between the chamber *a*, and the chimney *e*; *h* are angle-iron ledges, between which, and on two sides of the chamber, are placed carriers or trays *i*, made of wire-netting framed with wood, upon which trays the tea leaf can be placed, and which are inserted and taken out through openings provided for the purpose in the sides of the chamber. Hopper shelves *j*, and a perforated metal tray *k*, supported upon a shelf *l*, are provided for collecting any leaf

which may fall from the other trays *i*, a suitable opening for inserting and taking out the tray *k*, being also provided.

In operation the several leaf trays *i*, are interchanged in position.

This apparatus is one that has been found to be particularly suitable for the tea factories on small plantations, and which is also much used in large factories for the final firing of tea which has been partially desiccated in larger dryers, and likewise for the re-firing of tea before packing.

The main feature of this machine, as has been already mentioned, is the employment of a self-acting upward current produced by natural means, and without the aid of a fan. This current is formed by the conjoint operation of the combined air and smoke chimney and the air heater, or stove, which latter is located beneath the drying chamber containing the wire web trays on which the leaf to be dried or desiccated is spread, no mechanical motive power at all being required.

The number of superimposed trays, that is to say, of trays placed directly over each other, in one tier or column, in all machines of this class, is four, it having been found that the employment of a large combined air and smoke chimney, leading the exhaust air out through the roof, is capable of producing or inducing a current of air of sufficient strength through the layers of leaf on this number of trays, to insure the freshly introduced rolled leaf on the uppermost of the four trays receiving a sharp enough heat to check fermentation, almost the instant that it is inserted into the drying or firing chamber.

In the most recent pattern of this machine the air duct located above the trays is fitted with valves which admit of the strength of the air current being suitably controlled, but, even without the use of these valves, the volume of heated air passing up through the trays will be very efficiently and almost automatically regulated by the operation of the combined air and smoke chimney, whereby as the temperature of the air heater, or stove, rises, and a larger amount of waste heat will consequently be discharged from the smoke chimney, a greater draught of the hot air through the trays will be simultaneously produced, whilst if the temperature of the air heater should fall the strength of the air draught will be equivalently diminished.

The air heater, or stove, is constructed of cast-iron, and is of the vertical flue type. The combined air and smoke chimney rests or is supported upon a water collar on the top of the air duct leading from the drying chamber, so that any moisture that may descend the chimney, either as the result of condensation or during wet weather, will be caught in this water collar and will be conveyed by a drain pipe from it to the exterior of the factory, or can be run into a suitable receptacle. The smoke chimney from the air heater, or stove, leads into the base of the air chimney.

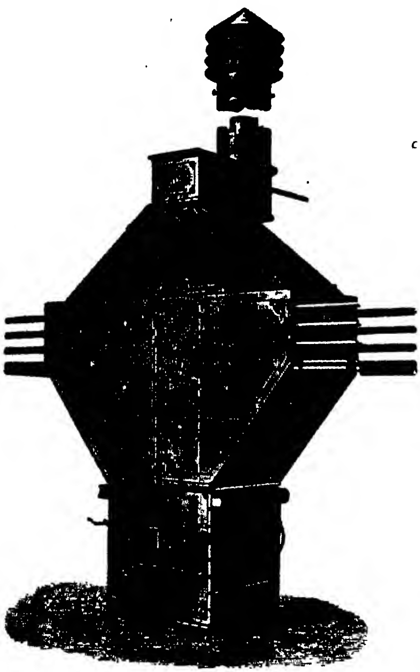


FIG. 112—Eight-Tray Non-Automatic Up-draught Tea Drying Machine, End Slide Type (front perspective view).

The capacity of this machine is about half or three-fifths of a maund (40 or 50 lbs.) of fully-dried tea, with a fuel consumption of from 30 to 40 lbs. of wood, or about 20 lbs. of coal.

The approximate dimensions of the machine are: length, 6 feet 2 inches; width, 5 feet 5 inches; and height, 10 feet.

Figs. 112 and 113 show a front and rear view of a recent pattern of non-automatic self-acting up-draught drying or firing machine, which is constructed with either eight or twelve trays.

The principle upon which these machines work is precisely the same as that of the small four-tray machine, which has been jus

described, the only difference in the eight or twelve tray machines being in the number and arrangement of the trays (two or three columns or tiers of four trays each) in the drying or firing chamber.

The machine shown in the illustration is called an end slide machine, from the fact that the trays, which are mounted in superimposed rows or tiers of four trays each, are arranged to deliver at the ends and slide through one in front of the other, from one end of the drying or desiccating chamber to the other.

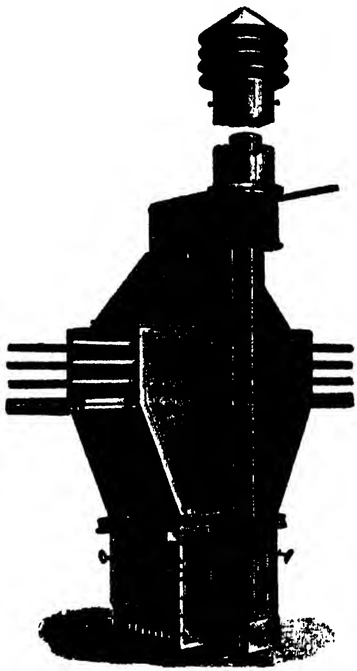


FIG. 113.—Eight-Tray Non-Automatic Up-draught Tea Drying Machine, End Slide Type (rear perspective view).

An eight-tray machine such as that depicted has two columns of trays, each consisting of four superimposed trays, and in a twelve-tray machine there would be three similar columns, the number in each column being always the same, and three columns being found to be about the greatest number that can be manipulated with ease.

Above each column of trays is provided a sliding valve or damper, by which the strength of the current of air passing through the trays can be controlled, the handle for regulating the opening or closing of the valves or dampers projecting through the air duct at each end of the machine, in such a manner as to be conveniently within reach of the attendant.

In practice it is usual to so erect these machines that the air heater, or stove, will be situated in a pit formed in the floor of the

factory, in which case the trays will be situated at a suitable height for the attendant to be able to work them from the floor level.

The approximate dimensions of the eight-tray end slide machine are: length, 11 feet 7 inches; width, 5 feet 4 inches; height, 13 feet 3 inches; and those of the larger or twelve-tray machine, length, 15 feet 2 inches; width, 5 feet 4 inches; height, 14 feet.

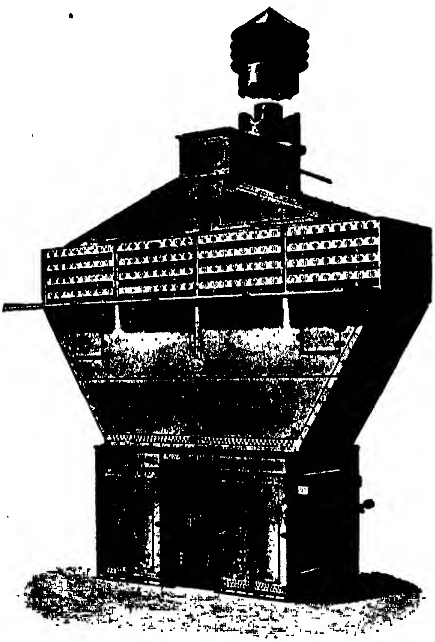


FIG. 114.—Sixteen-Tray Non-Automatic Up-draught Tea Drying Machine, Side Drawer Type, mounted on Multitubular Air Heater (front perspective elevation).

Figs. 114 and 115 illustrate the front and back of a sixteen-tray side drawer, non-automatic, self-acting, up-draught machine.

In the drawings, for convenience and to save space, the front perspective view (Fig. 114) shows a machine with the drying or desiccating chamber mounted upon an air heater, or stove, of the multitubular type, whilst the rear perspective view (Fig. 115) shows the same drying or desiccating chamber mounted upon a vertical flue air heater, or stove.

The arrangement of the trays is, it will be seen from Fig. 114, entirely different from that of the previous machine, but the number in each column is still kept the same. In point of fact, the arrangement resembles that first described with reference to the small four-tray machine, that is to say, four superimposed trays are arranged so that each individual tray can be separately pulled out

at the side of the machine; in this case, however, four such columns are provided instead of one.

An advantage possessed by this pattern of machine is that it obviates the difficulty which would be experienced in pushing four trays in line, each with a full charge of leaf upon it, as must necessarily be done in the case of machines of the end slide pattern when the latter are fitted with four columns of trays.

A multitubular pattern of air heater, or stove, having about fifty per cent. greater width, and larger air passages, which give a freer flow of hot air to the drying chamber above, the trays of eaf in a machine fitted with an air heater, or stove, of this latter description will receive in consequence a more plentiful supply of hot air, and the machine will, therefore, be capable of turning out a larger quantity of fully dried tea than that fitted with a vertical flue air heater, although the drying chambers are in both cases of the same size.

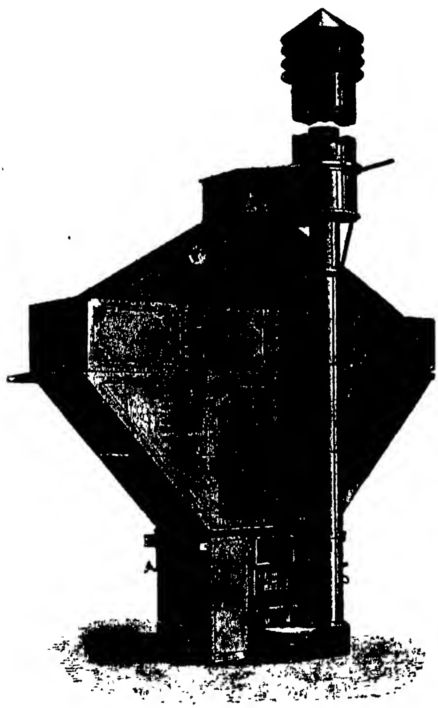


FIG. 115.—Sixteen-Tray Non-Automatic Up-draught Tea Drying Machine, Side Drawer Type, mounted on Vertical Flue Air Heater (rear perspective elevation).

The approximate dimensions of a sixteen-tray side drawer machine fitted with a multitubular air heater are: length

15 feet; width, 8 feet 7 inches; and height, 15 feet 5 inches. When mounted on a vertical flue air heater the length is 15 feet; width, 7 feet 10 inches; and height, 17 feet.

Fig. 116 represents the form of tray used in Davidson's up-draught drying machines. As will be seen from the illustration, which shows an underside view and a front elevation of the tray, it closely resembles that used in the non-automatic machines of the down-draught pattern, which tray has been previously shown in Fig. 110, and consequently the construction of the present one will be sufficiently apparent from the drawing without the need of any further description.

A number of other tea-drying machines have been devised which are adapted to work on the non-automatic up-draught principle; space, however, will only admit of a few of them being very briefly described.

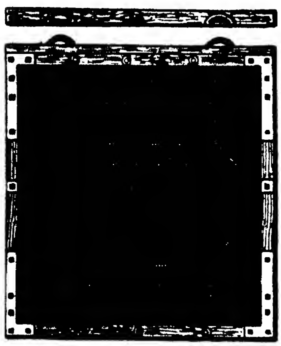


FIG. 116.—Tray for use with Up-draught Tea Drying Machine (underside view and front elevation).

An apparatus devised by H. Hemans of that class where the tea is laid upon shelves and dried by heated air, consists of a drying chamber provided with horizontal divisions, each composed of a floor of corrugated metal, supported on L-section frames. The heated air is directed through the divisional spaces by a series of baffles of unequal length linked together and hinged below. In conjunction with dampers, and the position of the above-mentioned baffles against or away from the divisional spaces, the air can be caused to pass in the one or the other direction. Each tray has a wire-work bottom, with perforated sides, and front and back plates, and the trays are carried on rollers on the frames, and can be withdrawn by handles attached to wire ropes, one placed on each side of the trays.

In a machine for drying tea, designed by G. Greig, the tea is spread on perforated trays, sieves, or drawers, having perforated covers, and arranged in tiers one above another on each side of a

central chamber, into which air is blown by means of a fan. The spaces between the drawers are fitted with partitions pivoted so that they may occupy positions inclined in either directions from the drawers above to those next below, thus causing the air current which enters at the central chamber to pass through the trays or drawers in the one or the other direction. When the trays or

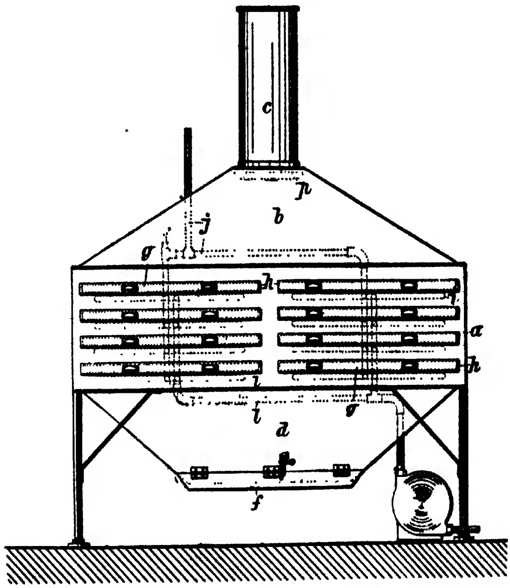


FIG. 117.—Eight-Tray Non-Automatic Steam-heated Tea Drying Machine (front elevation).

drawers are withdrawn hinged shutters, normally held open by brackets on the drawer frames, close the openings. Cords and handles are provided for operating the uppermost shutters.

NON-AUTOMATIC STEAM-HEATED DRYING MACHINES.

This type of non-automatic tea-drying machine, by reason of the form in which the heat is applied, viz., by means of steam-heated pipes, is practically safe in use, and in fact renders the burning or smoking of the tea an impossibility.

The machine which is illustrated in Figs. 117 to 120 has been

devised by G. W. Sutton, and is known as the "Safety" tea dryer, the heating medium, as in the case of the automatic machine devised by the same gentleman, being an arrangement of steam-heated coils, in this instance arranged beneath columns of superimposed trays.

This machine is made in a number of different sizes, and will dry 7 lbs. of tea per tray per hour from the green state. It is particularly suitable, however, for finishing off and final firing, owing to the immunity which it enjoys from over-firing or burning of the tea.

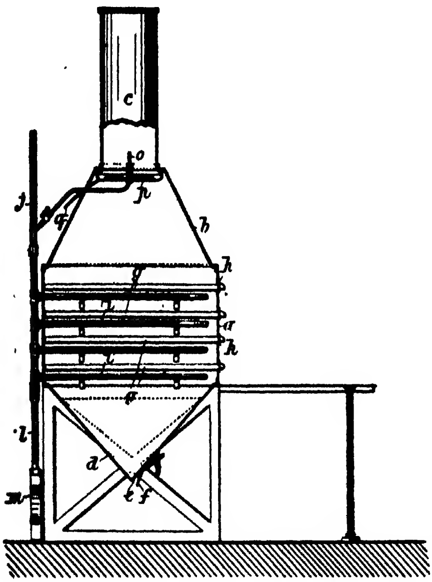


FIG. 118.—Eight-Tray Non-Automatic Steam-heated Tea Drying Machine (transverse section).

The steam coils admit of a constant temperature of from 200 to 300° F. being maintained with a boiler pressure of from 70 to 80 lbs., an even and unvarying temperature being secured by means of a reducing valve and a steam trap.

A great advantage possessed by these machines is that they are ready for work in a few minutes after the steam has been turned on; moreover, there are no working parts to wear out, or furnaces to corrode or burn out, and only one attendant is required to each dryer.

The supports for the trays consist of coils of tubing through which steam is caused to circulate. As each tray rests upon its own coil, and as all the coils are connected with the same steam supply, it will be obvious that a very uniform drying can be obtained, and that the heat can be maintained very

uniformly at any desired temperature by regulating the steam pressure.

The steam trap, arranged in conjunction with the coils, removes the water of condensation.

In the illustrations the machine is shown in front elevation, and in vertical and horizontal section, Fig. 120 being drawn to a larger scale to allow of certain details of construction being more clearly seen.

The casing *a* of the apparatus, which forms the drying chamber, is provided with a pyramidal top *b*, terminating in a chimney *c*, for the escape of the moist air, the bottom *d* being formed with

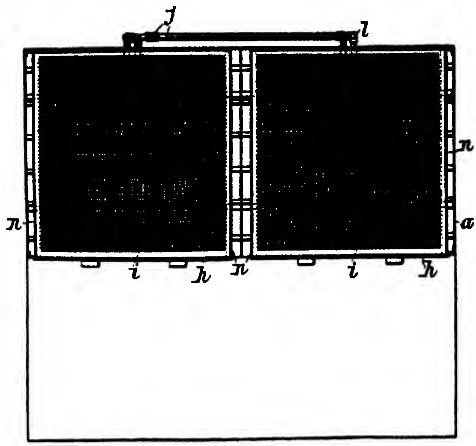


FIG. 119.—Eight-Tray Non-Automatic Steam-heated Tea Drying Machine (horizontal section).

inclines so that any tea which may fall upon it will gravitate towards an aperture *e*. The aperture *e* also serves for the admission of air into the chamber *a*, an adjustable door *f* serving to control the air current into and through the drying chamber.

g are the trays for receiving the tea to be dried, which trays are so constructed as to be capable of being introduced into and removed from the casing drawer-wise, and the fronts of the trays having flanges or lips *h* which insure the closing of the openings through which the trays slide.

In the machine shown in the drawing the trays are arranged in two columns or tiers of four each, but obviously machines with a greater or lesser number of trays arranged in a column or tier, and adapted to contain one column or tier only, or several columns or tiers, may be constructed.

Underneath each individual tray is arranged an independent steam-heating coil *i*, and each of these coils is connected at one end to a steam supply pipe *j*, and at the other end to a steam discharge pipe *l*, a steam trap *m* being provided for the discharge at suitable intervals of the water of condensation.

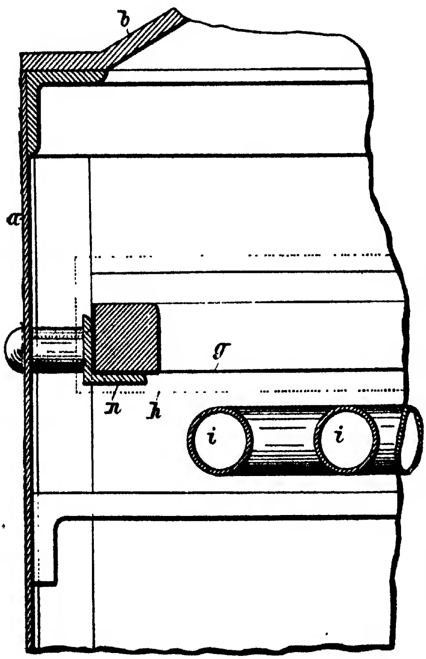
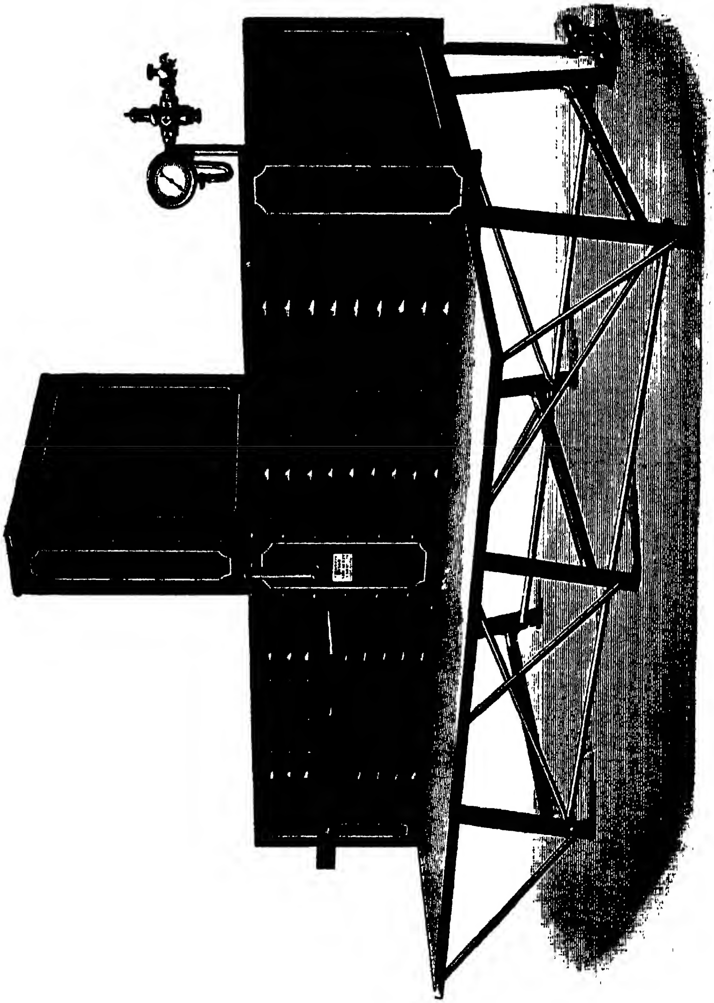


FIG. 120.—Eight-Tray Non-Automatic Steam-heated Tea Drying Machine (detail view drawn to an enlarged scale).

The coils in the machine shown are of a serpentine form, but in other machines they are arranged spirally.

The trays are supported by angle-iron guides *n* (Fig. 120), fixed at a short distance from the wall of the casing, so that spaces or clearances are left between the guides and the wall to allow of the moist air or vapour escaping from the leaf on the trays passing to the chimney.

So as to accelerate the draught through the chimney *c*, and consequently to more quickly draw off the vapour, a steam nozzle *o*, connected with the steam supply pipe *j*, is provided, thus admitting of a steam jet being employed if desired to force the draught.



To prevent water resulting from the condensation of steam in the chimney from falling into the trays, an annular trough *p*, having a discharge pipe *q*, which extends outside the casing, is fitted in the chimney.

The whole of the casing is preferably covered with lagging, or coated with non-conducting material, when the machine is in use.

Fig. 121 shows one of the most recent patterns of this type of machine, patented by G. W. Sutton, and constructed by the Blaxton Engineering Company, Limited, London, which although differing somewhat in design from that just described, so far at least as the minor details of construction are concerned, is yet identical in principle.

This apparatus consists essentially of an iron casing having the sixteen trays arranged to slide in and out, and a steam coil being placed under each tray. Each coil is connected by a vertical supply and discharge pipe, and a steam trap is placed on the latter, as shown in the right hand back corner of the illustration. A bye-pass is also provided for admitting of the water of condensation being discharged when starting work. On the steam supply pipe is provided, moreover, a reducing valve and a steam gauge, and a thermometer is mounted centrally on the machine, although this latter is not found to be of much practical value, inasmuch as it is impossible for it to register the temperature to which the tea is being subjected with any degree of accuracy. The greatest heat is given off from the coils immediately below the trays, and the temperature at these points is what it would be desirable to ascertain, but it is of course quite impossible to place a thermometer for that purpose. As at present arranged, the thermometer merely registers the temperature of the air after it has finished its work, and the makers recommend that it be entirely dispensed with, as the steam gauge is sufficient to indicate the temperature, the pressure of the exact temperature required being easily regulated by the reducing valve.

CHAPTER X.

DRYING OR FIRING MACHINES CONTINUED.

Electrically Heated Drying or Firing Machines—Miscellaneous Types of Drying or Firing Machines.

ELECTRICALLY HEATED DRYING AND FIRING MACHINES.

DRYING and firing machines in which electricity is employed for heating purposes have been devised, but owing to the expense attending this mode of procedure, and for other reasons, they have not as yet come into general use.

The following brief descriptions of two electrically heated drying and firing machines will serve as typical examples of the class:

A drying apparatus devised by J. M. Boustead, in which electricity is used as the heating medium, comprises iron or other metal resistance coils, which may be coated with porcelain or the like. The heating frame is preferably of slate, but may be of any refractory material, the joints being tongued and grooved and fastened by pins. The coils are secured to hooks, those on one side passing through the frame and being connected to terminals to which the leads are also connected, and those on the other side being attached to metal plates secured to the frame. If the frame be of metal, then the hooks and plates are suitably insulated.

In one pattern machine the tea is placed upon sieves located above or below the heating frames, and, in another, it is carried on an endless belt or apron over or under them. If the heating frames are placed over the sieves the heated air is drawn or forced downwards, the sieves being supported in the drying chamber upon ledges projecting from the inner casing. Air is admitted by dampers or valves, and after being heated passes through and over the sieves to the chimney.

The leads are taken through the casing in insulating tubes, and a switch is provided by which one or more of the heating frames can be cut out, so as to enable the temperature of the drying chamber to be regulated.

In a tea-drying machine designed by J. S. Stevenson, in which electricity is used for the supply of the requisite heat, the latter is produced by passing the current through a high resistance, or by an electric arc, or an electric furnace. The electric heaters consist of radiator plates mounted on metallic supports of perforated metal, upon which are embedded in insulating material wires of high resistance connected with a generator of electricity. The electric circuits are arranged in parallel, and one or more of them may be cut out by a regulating switch, and the heat generated reduced accordingly.

Air enters through openings regulated by dampers, and is heated in passing the radiators, and then passes over or through the tea on the trays and escapes up a chimney in which an exhausting fan is placed.

In one arrangement the trays are provided with openings alternately on the right and left of each of the trays, so as to allow of the air passing over the tea. In another, perforated trays are employed, so as to allow the air to pass through the tea.

MISCELLANEOUS TYPES OF DRYING AND FIRING MACHINES.

A very large number of machines for drying and firing tea, and of parts applicable thereto, which are not capable of being conveniently classified under the foregoing headings, and few of which have come into practical use, have been invented. Any attempt at a detailed description of these would naturally be an impossibility, but the following brief notices of the principal ones may prove of service to those interested in the subject, inasmuch as it will enable an insight to be obtained into what has been attempted in a general way in this direction, and that with a minimum expenditure of time and trouble.

Five tea-drying machines designed by W. A. Gibbs comprise, the first, an arrangement for enabling the hot products of combustion drawn from a furnace to be used for drying the tea, special hot-air distributing devices being employed. The furnace

is provided with a chamber for feeding fuel into the combustion chamber, and air is supplied through suitable orifices, and also through perforated plates in the first bridge and in a second hanging bridge. The hot air is deflected by a baffle plate and a splitting plate, and is drawn off by the fan into a cylindrical drying chamber, where it is distributed through louvres in a tube in which is placed an adjustable deflecting plate.

The tea is fed by a conveyer, which carries it through the entire length of the cylindrical chamber before depositing it.

When a screw conveyer is used the worm is made tubular, and steam or hot air is passed through it to partly dry the tea.

The second machine comprises an arrangement for heating air and mixing furnace gases with it, the latter being supplied to a chamber to which air for completing combustion is admitted through suitable flues. The gases pass from this chamber to an induction tube through annular spaces formed by one section entering another of larger diameter, through which induction tube air is driven. This heated air is conveyed to the drying chamber or cylinder.

When a higher temperature is required a rotating drying cylinder closed to the furnace gases is provided in another chamber. This rotating cylinder has an internal arrangement of interrupted rows of shelves, and its ends are frustrum shaped. In addition to the induction tube a series of air-heating pipes are arranged in the chamber below the tubes.

To enable the products of combustion escaping from the furnace of a portable or traction engine to be used for tea-drying purposes, an auxiliary smoke-consuming furnace and a fan are combined with it, the auxiliary furnace being secured to the smoke-box, and consisting of a tubular coil through which water from the boiler is caused to circulate. The lower part of this coil is filled with an incombustible material serving as a filter, such as limestone, and above this smokeless fuel is placed.

The third machine is so constructed that the heated air will be forced through two ducts and perforations, protected by louvres and wire-gauze respectively, into a rotating cylinder containing the tea to be dried. In this cylinder are shelves by which the material will be lifted and let fall between the two air ducts.

The speed at which the tea will pass over the louvres is

regulated by a travelling band fitted with scrapers, the curved portion of the air ducts being corrugated, and moreover only extending partly through the cylinder.

For finishing the tea, plain metal cylinders are used, and the shelves are so arranged as to allow the tea to slide gently from one to another, the ducts directing the air currents downwards upon the tea and collecting any dust driven in with the air.

The fourth machine comprises a rotating cylinder fitted with shelves, the heated air being supplied by means of a duct which consists of short lengths of different diameters arranged to telescope into each other for purposes of transport. Shelves are also provided, which, together with the ducts, form trays adapted to receive the tea from the ascending side of the cylinder, and pass it to the descending side of the cylinder, the duct being rotated in the same direction as the cylinder. Longitudinal conduits and perforations are provided for the passage of the hot air, and its too rapid escape from the cylinder is prevented by transverse baffles of wire-gauze attached to the duct.

Lastly, the fifth machine is so arranged that the tea will pass in a downward direction through a chamber fitted with sloping shelves or deflector plates, and having a central air-duct with openings at intervals into the drying chamber and sloping shelves or deflector plates.

Heated air is drawn through this air-duct by a fan, and screw conveyers carry off the dried tea from the lower part of the drying chamber.

In a drying machine devised by A. A. Van Delden the tea is dried in a rotary cylinder divided by longitudinal partitions into compartments, and provided with a central perforated hot-air duct. These compartments are fitted with stirrers, and the cylinder is perforated and provided with perforated doors arranged symetrically.

A drying machine designed by J. Walworth comprises an inner cylindrical chamber of wire-gauze or perforated sheet metal, having a conical top and surrounded by an outer casing of similar material, so as to leave an annular clearance between them. The tea is fed in through an aperture in the top of the outer casing, and falls upon the apex of the inner chamber, and thence down into the annular clearance. Heated air forced into the inner

chamber passes through its walls to the tea, and flanged distributing rings are provided in the annular clearance.

A combined machine for both drying and sifting tea, devised by A. H. B. Sharpe, comprises an arrangement by which the tea is fed through an opening to a series of rotary drums having vanes which raise the tea and deposit it upon the next drum, by which it is delivered to a casing containing a series of inclined adjustable sieves. This casing is suspended on spring hangers, and is oscillated by a suitable shaft.

The sifted tea is, in one arrangement, discharged through doors in the latter casing and in the outer casing respectively, and in another it is passed over the whole series of sieves through openings, and is then discharged into receptacles. The heated air enters the apparatus through an aperture communicating with the inner casing, and is drawn through the sieves by an exhaust fan.

In a drying machine invented by R. Howarth the tea is fed into a perforated cylinder, which is rotated slowly by worm gearing, in a chamber divided into compartments by strips of metal covered with felt. One of the above-mentioned compartments is connected to an air trunk, and the heated air or gases are drawn through the perforated cylinder from this compartment by a fan. Cold air can be admitted when desired by a slide at the bottom.

A tea-drying machine designed by E. Robinson comprises quadrant-shaped open-work frames or boxes carried upon longitudinal T-irons and forming in sets of four a series of drums, the heated air being discharged by nozzles in a central hollow shaft or tube into the spaces between them and an outer cylinder arranged to rotate upon the latter.

In another arrangement the outer cylinder is stationary, and the drums are caused to revolve.

The tea-drying machine invented by E. Keighley comprises an outer rotating vessel in the form of two truncated cones, and having two internal cylinders, one of which extends for the whole length of the machine, and is heated on its inner surface by means of jets of steam, or by an oil furnace, etc., the products of combustion passing out through a suitable chimney. The inclined shaft upon which the machine is supported is protected from the injurious effects of heat by a sleeve. The second cylinder is of larger diameter than the inner one, and does not extend throughout

the entire length of the machine, the lower end passing inside a cylinder placed at the bottom of the machine. Between these two cylinders is an annular space or clearance containing a series of wings, and also a screw conveyer, to pass the tea under treatment from end to end of the machine, and keep it for a sufficient length of time in contact with the hot cylinder.

A suitable stationary feed hopper is provided, as also discharge doors in the outer vessel, into which the dried tea finally falls.

A machine applicable for either drying tea or for withering or limping the leaf, devised by J. Greig, comprises a slowly rotating wire-meshed drum formed of two plain sides joined together by an inner and outer circumference of wire cloth, and into which drum hot air is drawn by a fan, and is then forced through the meshes so as to act on the tea. The annular space of the drum is divided into compartments by radial divisions of wire cloth in which the tea is loosely placed.

A form of drying machine devised by S. C. Davidson comprises an apparatus for circulating, by means of a fan, air, vapour, gases, or admixtures thereof, in the drying chamber. The air from the fan is passed into the chamber through a series of telescopic pipes arranged near the ceiling and having their outlets uppermost. The return pipes are located near the floor, with their inlets below leading into the eye of the fan. The air is heated either by steam pipes, stoves, gas burners, or by chemical substances. As the moisture is withdrawn less quantities of air are admitted until the same air is continually passed through the chamber. Where heating stoves are employed they are preferably located on the pressure side of the fan. The cooling of the chamber is effected by cutting off the hot air and admitting cold air. The use of double chambers admits of continuous working. This apparatus is practically analogous in principle to that already described for withering the leaf.

An improved metallic travelling sheet or apron for use in tea-drying machines, designed by W. Whiteley, comprises certain improvements intended to obviate a drag or pull being thrown on the cross-bars instead of on the chains, and thus tends to prevent or reduce the objectionable stretching of the apron.

This purpose is effected by providing additional links between the actuating chains through which the cross-bars pass, and

which links are jointed to additional rods whose ends are carried in the links of the actuating chain.

Endwise movement of the rods is obviated by a hollow rivet placed in each link, into which the end of the rod is placed and prevented from working in an endwise direction by a screw. The cross bars are secured in position by means of clamps.

A tea-drying machine designed by W. Watson consists of a cylindrical casing, provided with a number of radial screens rotatably mounted on a suitable shaft, a hinged door and a discharging slide being also provided.

The drying chamber being charged, heat is applied by an atmospheric or other burner. The steam given off is condensed and caused to fall back by the employment of a suitable valve on the vessel, this latter consisting of a casing having a fixed lid and a flue covered by an adjustable cap and surrounded by water. During the steaming process the cap is screwed down, and the steam passing up the flue is condensed and falls back. After the steaming process is finished, the cap is raised and the steam condensed by contact with the water, until finally the tea becomes quite dry, when it is withdrawn through a suitable slide.

In a tea-drying machine invented by H. Williams the tea is fed through a hopper into the uppermost of a series of slightly inclined tubes arranged one above another, the tea being passed along each tube by a worm or other suitable conveyer, and after passing in zigzag fashion through each tube in succession is finally delivered from the discharge end of the lowermost tube. Hot air is forced or drawn through the apparatus, being admitted at the bottom and escaping at the top.

In some patterns revolving valves are provided for regulating the feed and discharge of the tea, and the capacity of the apparatus may be increased by arranging two or more tubes side by side on the same level.

The whole is inclosed in a casing the space between which and the tubes is filled up with sand, ashes, or other non-conducting substance, which will have a tendency to check irregularities of temperature.

In a machine designed by A. H. Hobson the tea is dried in an inclined revolving drum having two sets of cross-partitions so arranged with regard to one another that as the drum revolves

the tea will be transferred from one set of partitions to the other, and traversed in a zigzag fashion through the drum.

The tea is fed by a hopper into the upper end of the drum, and will be discharged from a chamber situated at its lower end by means of a weighted door. Dried or heated air or products of combustion are admitted to the chamber, and escape from the upper part of the apparatus through a flue.

In another arrangement the drum is inclosed in a steam jacket, and the partitions are so mounted in the drum that they can be adjusted to any desired inclination, and can be easily removed for cleaning purposes.

A tea-drying machine invented by R. White operates by passing a current of hot air once over the tea to be dried, the latter being deposited upon wire-gauze trays which are placed, one on the top of the other, in other trays having corrugated bottoms and perforated sides, and of such a height that they are capable of holding three of the first-mentioned wire-gauze trays. The trays are placed on shelves in the middle chamber of a casing, each half of which is divided into three compartments, the end ones of which are provided with partitions forming channels for the air current, which latter passes through the apparatus in a direction which is governable by a suitable valve.

The casing is hopper-shaped, and the central division extends downwards for a short distance into a pyramidical-shaped part beneath, the apex of which communicates with an air-heating furnace provided with a corrugated crown above which is a plate from which vertical plates project in a downward direction between the corrugations, causing the air admitted at the bottom to take a circuitous course over the crown of the furnace before entering the drying chamber.

A modified form of this machine subsequently designed has partitions pivoted at their ends and connected together by links in the end chambers, so that the whole of the partitions are capable of being moved together into the one or the other position according to the direction in which the air current is desired to pass.

Partitions are also provided which form, in conjunction with the casing tubes, valves by which the direction of the air current can be regulated.

The air-heating furnace consists of a fire-box having three flues on each side, which communicate with tubes leading to the chimney.

In a drying machine devised by Main and Drew, the tea is dried on trays placed the one above the other in racks arranged in pairs back to back across the width of the drying chamber, and with a passage between each pair of racks. The racks are mounted on a raised platform, and the backs of each pair are supported by vertical standards on which are fixed cross-pieces, arranged one above another, for the superposed trays, the cross-pieces on the same horizontal line being connected by wires or rods. The fronts of the trays are provided with hooks which engage on tubes, which are supported in eyes formed by bending the channel supports. The top, sides, and ends of the racks are covered with canvas or other suitable material, and a current of air is forced or drawn in either direction at will through them by means of a fan, and passes to suitable openings through a duct, a valve being provided for causing the current to flow in the desired direction.

Two machines for drying tea devised by J. D. Cahill comprise, the first, a rotating vessel of cylindrical or other form, heated externally by any suitable means, and wherein he proposes to subject the tea, in order to improve its quality, to the action of air heated to about 180°. In the second the rotating cylinder is carried on adjustable bearings, and is provided with inclined ribs into which the tea is fed from a hopper.

A method of drying invented by O. C. Hagemann consists in the extraction of moisture, essential oils, and other volatile bodies, from the tea, by subjecting the latter to the action of gases or vapours, and afterwards fixing or absorbing them by glycerine or other suitable substance.

In this way it is claimed that moisture can be removed from the tea by means of carbonic acid gas, nitrogen, or other gas, which will have no chemical action on it, and the moisture afterwards abstracted from the agent by glycerine, sulphuric acid, deliquescent salts, or other substance which does not absorb the gas itself, and from which the moisture can afterwards be easily separated.

In a tea-drying machine designed by P. S. Smith the exhaust

Q 2

steam from the blower or fan engine is passed into the chimneys of the boiler and of the air-heater, to increase the draught, and the waste furnace gases are delivered into the air-heating apparatus and there utilized, the heated air after passing through the dryer being conducted to the furnaces of both the boiler and air-heating apparatus, and arrangements being also made for supplying these furnaces with hot air direct from the air heater.

The apparatus for drying tea devised by Tomkins, Cracknall, and Courage consists of a kiln, the floors of which are made of double its length, and are so arranged that they can be moved horizontally by rack and pinion gearing, one-half of each floor being thus available for recharging whilst the tea is being dried on the other half. The tea is disposed on trays so as to be capable of being readily moved to different parts of the floors.

Air drawn or forced through a heating apparatus and the floor passes out through a central flue.

An outer casing surrounds the kiln, and the intervening space or clearances are fitted with floors on which the preliminary drying operations can be carried on.

Two machines for drying tea designed by Main and Dick comprise, the first, a chamber divided by vertical partitions into three compartments communicating with each other by suitable doors, the central compartment forming the drying chamber in which the tea is spread upon a series of openwork trays supported upon racks, which latter are divided by transverse partitions into lengths corresponding to the length of the trays employed, and also longitudinally by an air-duct, equal in height to the racks, and having side openings fitted with fixed or adjustable louvres or boards for regulating the force of the air current. These side openings in the air-duct communicate with the space between the bottom of each tray and the framework below it, whilst the corresponding space above the trays is open at one side to the atmosphere of the drying room, and is fitted with regulating louvres. The object of this arrangement is to prevent the air which has been dried by passing over absorbents, and has passed through one set of trays, from passing through the others before being renewed.

The air-heating apparatus is located in one of the end compartments, and the exhaust fan in the other one.

The second machine has an arrangement by means of which air is dried by passing it through the perforated hollow rim of a rotating wheel containing a drying agent, which latter may consist of pumice stone moistened with chloride of calcium. The hollow rim of the wheel traverses slowly across the air pipe so as to continually expose a fresh portion of the drying material to the air. At the opposite side of the spindle from the air-pipe, the rim of the wheel passes through a recess in a chamber exposed to the heat of a furnace so as to drive off the absorbed moisture from the drying agent.

After passing through the dryer the air-pipe splits into two branches, one of which leads through a heating chamber to an exhaust fan, and the other being taken direct to the fan, suitable valves admitting of the air being directed at will into either branch.

This apparatus is stated to be also adapted for withering or limping tea-leaf.

An apparatus for drying tea devised by J. Dick comprises two hollow sloping shelves, concave in transverse section and open at their inner ends, and perforations being provided on their upper surfaces.

These shelves are inclosed in a casing open at the top for the egress of the moist air, and they are fitted at each end with an arm attached to one extremity of a connecting rod the other end of which is secured to a pin fixed on the side of a toothed wheel driven by elliptical gearing. By this means the shelves can be raised slowly and lowered rapidly through an arc, so as to admit of the tea being alternately gradually poured from one shelf to another.

The air for drying purposes is forced into the casing or chamber, either through inlet apertures at the bottom, or through hollow trunnions, a hopper located at one side of the chamber being provided for intermittently feeding the tea to the shelves, and the finished or dried tea being delivered to another hopper at the other end.

An apparatus for drying tea proposed by Morris, Baker, and Francis consists simply of a conical-shaped kiln fitted about half-way down with a trellis framework covered with perforated tiles of fireclay, copper, or any other suitable material. In a well formed beneath the bottom chamber of this kiln is provided a

blast furnace, and in order to assist combustion and preserve the fire-bars this well is filled with water. At the top of the furnace is placed a suitable damper.

Two tea-drying machines designed by J. C. Allen comprise, the first, a drying chamber inclosing a wheel carrying blades on which are fitted movable trays made of wire netting, with doors of the same material provided with spiked cross-bars to prevent any accumulation of tea occurring in one place. An opening is formed in the drying chamber for the admission of hot air, which is driven by a fan through a furnace, or if charcoal fumes be employed a pump is substituted for the fan, and the drying chamber is placed between the pump and the furnace. An aperture is provided for the removal of the damp air from the drying chamber, and another aperture fitted with a suitable door for the insertion and withdrawal of the trays. A drawer is also provided to catch any tea-leaf that may fall out of the trays.

The second machine, which is also stated to be suitable for withering or limping the leaf, comprises a boiler connected with a furnace, through which boiler tubes pass to the drying chamber. In machines in which pure heated air is to be employed for drying, these tubes are passed right through the furnace and smoke-box into the drying chamber; but in patterns in which the fumes of the furnace are to be used they are stopped short at each end of the boiler, and a valve is provided for allowing these fumes to enter the drying chamber, on the top of which latter is located a chimney, a bye-pass being provided for passing the said fumes direct to the chimney when the chamber is opened for filling.

The drying trays are carried on a series of arms or spokes, so secured to a shaft revolving in the drying chamber as to be readily removable, and which arms are connected together by cross-pieces. A guard consisting of a frame of bars covered with wire-gauze is hinged or pivoted to each of the inner cross-bars and fastens over the tray, to hold it in place, by means of a spring catch.

The trays are composed of frames covered at the bottom with wire-gauze, and strengthened by tie-rods, zigzag pieces of hoop-iron being fixed edgewise across the trays to divide them into separate compartments.

A space left between the tray holders and the shaft admits of the passage of the heated air, and adjustable deflecting plates or baffles

may be used at the hot-air inlets to direct the current well across the chamber and in a radial line towards both sides of the trays.

The steam generated in the boiler may be used in the engine for driving the rollers and other machinery, or otherwise.

The apparatus is shown in vertical section in Fig. 122, in which *a* is the boiler, *b* is the furnace, and *c* is the drying chamber.

A machine for drying tea, designed by J. Norman, consists, as shown in Figs. 123 and 124, of a long semi-cylindrical iron or wooden casing, the upper part of which has inclined sides and a flat top, and which is so constructed that it can be fixed together by cast-iron frames connected by other frames, and supported in an inclined position on several brackets or standards.

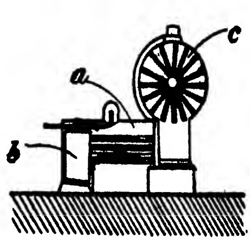


FIG. 122 — Rotary Tray Tea Drying Machine (vertical longitudinal section).

A tubular shaft mounted in the above-mentioned casing is so arranged that it can be rotated through bevel or mitre pinions,

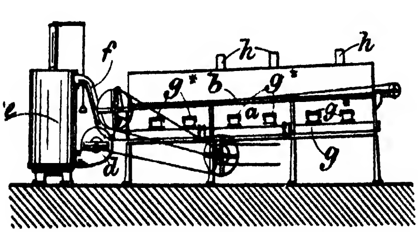


FIG. 123.—Rotary Tray Tea Drying Machine (side elevation).

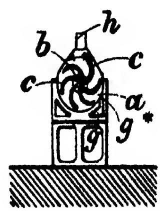


FIG. 124.—Rotary Tray Tea Drying Machine (transverse section).

driven from any suitable source of power. Upon this shaft is secured a series of cast-iron collars, having curved arms to which are fixed long concave metal or wooden trays, between the inner edges of which and the shaft a certain clearance or space is left.

A travelling apron feeds the tea-leaf into the apparatus, and it is then directed by inclined planes on to the trays. During the revolutions of the shaft the tea-leaf will be turned over and over, falling from one tray to another through the open spaces near the shaft, whilst at the same time it will be gradually passed to the

lower end of the machine, where it will be discharged through a door which is opened and closed automatically by means of an arrangement of levers operated by a pin or projection on one of the bevel or mitre wheels.

Heated air is forced into the casing by means of a fan, the air being first driven into a vertical, cylindrical fire-box fitted inside an outer cylindrical shell, from which it passes in an upward direction through horizontal tubes fitted in a cylindrical combustion chamber, and into a tube or conduit running the entire length of the drying chamber and communicating, at suitable intervals, with the latter through branch pipes fitted with valves or dampers, which latter enable the supply of hot air to be regulated.

Funnels in the top of the casing admit of the escape of the vapours, etc., given off from the tea.

The heated air is in some machines also supplied to the drying chamber through the hollow or tubular shaft.

In the illustrations, *a* is the semi-cylindrical casing, *b* is the tubular or hollow shaft, *c* are the trays, *d* is the fan or blower, *e* is the combustion or heating chamber, and *f* is the hot-air tube, which is connected with a horizontal conduit *g*, fitted with branches *g**. *h* are the funnels provided in the casing *a* for the escape of the vapours, etc., given off from the tea.

A somewhat similar drying machine, previously designed by the same gentleman, consists of a cylindrical casing so mounted as to have a slight inclination from the horizontal, and in which casing is mounted a rotating shaft carrying centres with arms curved in the direction of rotation, and upon which arms are fixed trays, preferably formed of netting, cloth, or wire-gauze or mesh, but which might consist of sheet metal perforated or otherwise.

Through this cylinder is forced or drawn by a fan a current of air heated by being passed through a casing with a fire-box in it, the tea being fed in from a hopper by a feed screw and falling on the trays in succession through a narrow opening left between them and the central shaft.

CHAPTER XI.

BREAKING OR CUTTING, AND SORTING MACHINES.

Machines for Breaking, Cutting, or Equalizing the Tea—Machines for Sorting or Classifying the Tea—Miscellaneous Machinery for Breaking or Cutting, and Classifying or Sorting the Tea

BREAKING, CUTTING, OR EQUALIZING MACHINES.

TEA-CUTTING or reducing machines are employed for breaking down the tea previous to sifting, or for similarly treating the large leaves remaining after assortment.

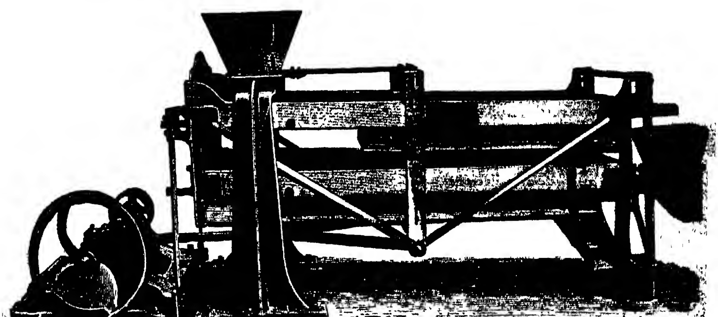


FIG. 125.—Combined Tea Sorting and Cutting Machine (perspective view).

It is very essential to choose for this purpose a machine of efficient construction, and to drive it at the proper speed to perform the best work, for if this latter point be not attended to, or a machine of inferior design, or one badly constructed be employed, a large quantity of dust will be produced.

A pattern of reducing machine which is said to give very good results in practical work is one which has been devised by W. & J. Jackson, and which is manufactured by Marshall,

Sons & Co., Limited. This machine, which is illustrated in Fig. 125, operates on a somewhat similar principle to the rolling machine designed by the same inventor. It consists essentially of two tables or shells, the uppermost of which is mounted or supported upon three cranks, and motion is transmitted to it from one of these cranks through suitable bevel or mitre driving gear, so as to cause it to move on the top of the other or lower table.

The uppermost table or shell is fitted with a grating divided into inch and a-half squares, through which the tea falls, and the bottom table is provided with galvanised iron wire mesh, through which the tea will be automatically forced, and will be cut to the desired length under the action of the upper table or grating.

The size to which the tea will be reduced can be readily altered by changing the mesh wire on the bottom table or shell, inside which the tea to be treated is placed.

Beneath the above-mentioned tables or shells is located a dust sieve which is suspended from the uppermost or moving table or shell by four hangers in such a manner as be adjustable vertically, the requisite shaking movement being thus imparted to it.

The machine is fitted with driving pulleys sixteen inches in diameter by three inches width of face, and the speed at which it should be driven is one of about 110 revolutions per minute, the power required to drive being merely nominal.

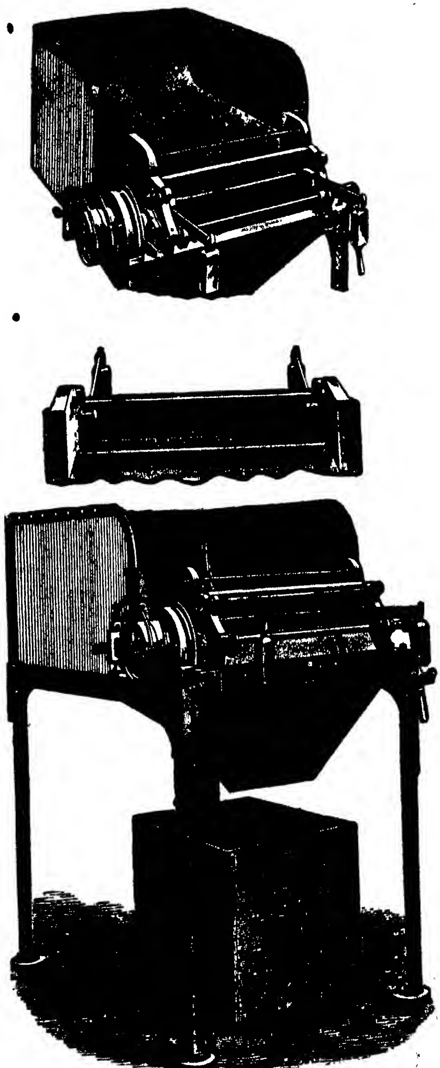
As regards the capacity of the machine, this will of course vary to a considerable extent in accordance with the quality and condition of the leaf fed into it, but it may be taken as being capable of reducing or breaking on an average from 320 to 480 lbs. of tea per hour.

A machine for reducing or breaking tea, devised by S. C. Davidson,* is shown in Figs. 126 to 128. This machine consists of a tea-cutting mill mounted on a stand containing a large receiving bin or hopper for the tea to be treated. It may be used either for the purpose of imparting to the bulk tea from the dryers a slight breaking cut before it is passed on to the sorting machines, or for treating the tailings from the latter.

The cutting mill consists essentially of a feeding and cutting roller and of what is termed a resistance plate, the former having both

* Manufactured by Davidson & Co., Ltd., Belfast.

sharp-edged longitudinal flutings and relatively deep grooves at right angles across the latter situated about one and a half inches apart. Into these last-mentioned circumferential grooves project knife-edged teeth fitted into the lower edge of the resistance plate, so that when any extra long-leafed tea is fed up to the roller lengthwise to the flutings, it will meet and be cut by the teeth in the resistance plate, no leaf of a greater length than 1½ inches being in consequence able to pass through the cutting mill. The resistance plate is mounted on hinges or pivots, and it is



FIGS. 126, 127, and 128.—Tea Leaf Breaking, Cutting and Equalizing Machine (perspective elevation and detail views).

weighted in the manner clearly shown in the illustration, so that it will be held sufficiently firmly in position against the tea to be cut, whilst at the same time being capable of giving way and swinging back freely should a nail, piece of bamboo, stick, or other foreign substance or obstruction of a hard nature become interposed, thus letting any such substance pass through without in any way damaging the cutting flutes of the roller, and afterwards instantly dropping back again into its normal position.

The resistance plate is also so arranged as to be very readily adjustable to or from the longitudinally fluted and circumferentially grooved feeding and cutting roller, by means of an adjustment screw on the hand lever attached to it, on which a scale is provided to indicate the amount of clearance given.

The detail views shown at the top of the drawing illustrate, the first, the feeding and cutting roller with the hopper door-plate removed, so as to allow the teeth in the lower edge of the resistance plate to be seen, as also the flutings, and the circumferential grooves in the roller; and, the second, the roller from the opposite side of the resistance plate, the latter being shown raised to a larger clearance than that usually employed during actual work, so as to more clearly demonstrate the spaces through which the tea passes between the teeth of the resistance plate and the flutes of the feeding and cutting roller.

The feeding and cutting roller is interchangeable, and when the machine is used for giving the unassorted bulk only a slight breaking cut it should have the broadest and deepest longitudinal flutes, whilst when employed for reducing the size and thickness of coarse leaf or tailings, finer longitudinal flutes would be found to be more efficient.

The method of working the apparatus is very simple. The rough tea is thrown into the bin or receiving hopper situated on the top of the machine, from whence the attendant drags it forward with a rake to the longitudinally fluted and circumferentially grooved feeding and cutting roller, by which it will be taken up and passed against the toothed resistance plate, which latter, when the bulk tea from the drying machines is being run through, should be so adjusted as to give such an amount of clearance that the above-mentioned grooved feeding and cutting roller will only act as a feed regulator, whilst the teeth on the resistance plate will

just sufficiently separate the leaves from their connecting stems and from each other, as to allow of the fine teas sorting out with the smallest possible injury to the leaf.

When, however, the coarse tea is being passed through the machine the resistance plate should be so adjusted relatively to the fluted and grooved feeding and cutting-roller, as to break or reduce the leaf to a smaller size, so that the majority of it may be sorted out in the sieving machinery and only a comparatively small quantity pass out as tailings. On passing the tailings through the machine the resistance plate should be adjusted as close as possible to the feeding or cutting roller. The cut or broken tea is delivered by a hopper chute into a chest or other suitable receptacle placed below it, and it will be seen that no handling of the tea is required. The approximate dimensions of the machine on stand are: length, 4 feet 10 inches; width, 2 feet 9 inches; height, 4 feet 7 inches.

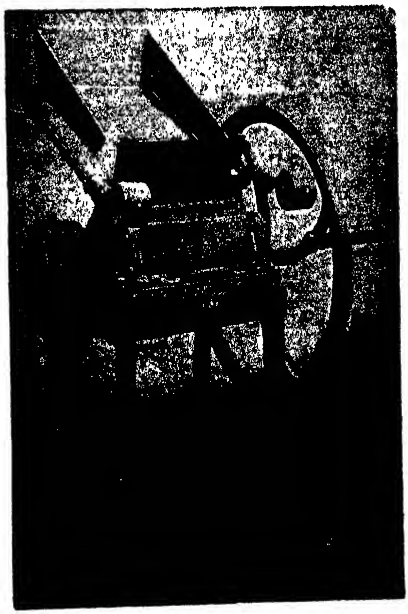


Fig. 129.—Self-feeding Tea-breaking or Equalizing Machine.

George Reid's improved self-feeding tea-breaking machine, the agents for which are Begg, Dunlop & Co., London, is illustrated in Fig. 129. This machine is extensively used in the Assam tea districts, and is said to be found to give very satisfactory results.

It consists briefly of a sheet iron hopper mounted on a cast-iron support, fitted with a sheet iron feed slip. A wire sieve is secured to the frame by means of angle-irons. The concave breast-piece is of malleable iron, and is provided with three rows of 21 teeth each for coarse cutting, and three rows of 28 teeth each for fine cutting. The revolving barrel is of cast-iron, and it is fitted with six rows of radially projecting malleable iron teeth, either 22 or 29 teeth being provided per row. The feed roll is mounted in the casing between the hopper and the revolving barrel, and it is driven off the spindle of the latter by means of toothed gearing.

It is claimed for this machine that it admits of breaking up or equalizing large quantities of tea without in any way destroying the appearance of the latter, and that it is capable, moreover, of breaking or equalizing the tea to any size, produces a minimum quantity of dust during the operation, and gives to the tea a regular and fine appearance, as it is not dulled or rubbed in any way so as to make it grey. All contact of the tea with the hand, moreover, is entirely obviated.

A considerable advantage possessed by this apparatus is that, all the parts of the machine being made to template, duplicates can be easily fitted at any time with comparatively little trouble. The sieves are supplied fixed to an iron frame which fits the machine, as shown in the detail view on the left-hand side of the illustration, and they can be fixed in position by means of four thumbscrews, so as to admit of their being readily changed. For double teas and Souchongs a No. 6 mesh sieve would be found the most suitable, but a No. 4 mesh sieve is also supplied with the machine.

The tea-breaking machine is driven by belt gearing from the engine shafting, or other source of power, the fast and loose pulleys on the drum spindle being 12 inches in diameter, and the requisite speed from 250 to 300 revolutions per minute; the power required for driving is merely nominal. At the opposite end of the drum spindle to the pulleys is provided a heavy fly-wheel. The machine is capable of breaking up to 40 maunds (8,200 lbs.) of tea per day with one lad to attend to it. It may be advantageously used to disintegrate the leaf before passing it through the sieves, or for breaking or cutting the coarser leaf before inserting it into the latter.

MACHINES FOR SORTING OR CLASSIFYING THE TEA.

Fig. 130 is a perspective view, looking from the front or feed end, and Fig. 131 is a similar view looking from the delivery

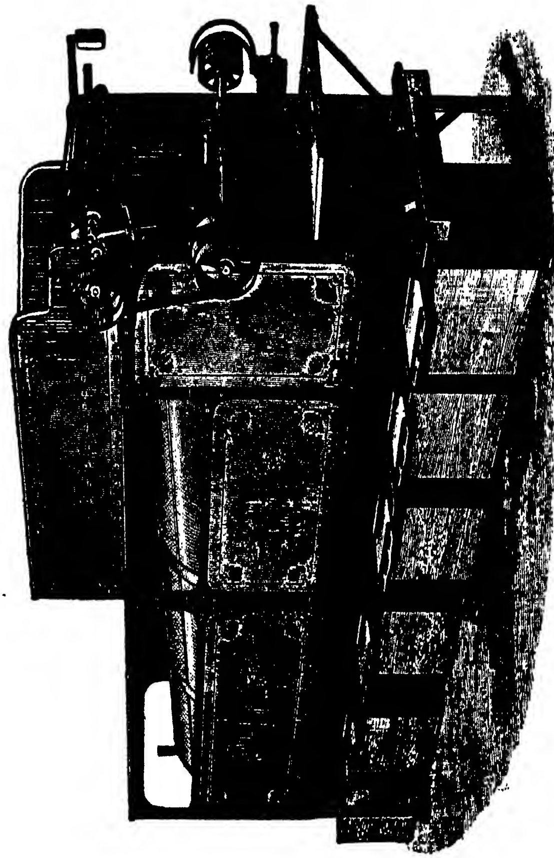


FIG. 130.—Tea Sorting or Classifying Machine (front perspective view).

end, and with the side sheets removed in this case in order to allow the interior of the hopper chutes to be seen, showing a combined tea-cutting and sorting machine, devised by S. C. Davidson, of Davidson & Co., Ltd., Belfast.

The cutting machine is practically similar in construction to that which has been previously described, except that it is of a larger size, and consequently it requires no further description.

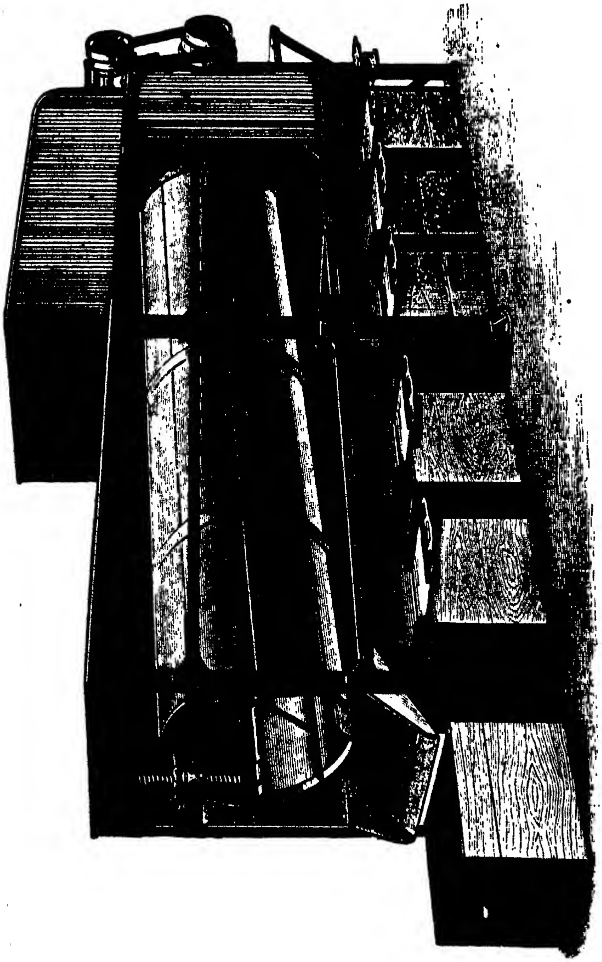


FIG. 131.—Tea Sorting or Classifying Machine (rear perspective view).

As will be clearly seen from the illustration, Fig. 131, a screw adjustment is provided, by means of which the delivery end of the

sieve can be raised or lowered, thus causing the tea to travel either at a slower or at a faster rate through it, and so rendering the sorting of the various grades somewhat finer or coarser, as may be desired.

The requisite rotary motion can be imparted to the cylindrical sieve by a special form of right-angle driving-gear which admits of the above-mentioned vertical adjustment of the delivery end being effected without in any way interfering with the working of the driving pulleys. This method of driving, moreover, absorbs so little power that the machine can be easily driven by hand, when hand driving-gear is fitted for that purpose.

The cylindrical sieve or sorter is provided with an outer frame formed of longitudinal ribs constructed of a light but very strong section of steel angle-bars, which latter are riveted to extra strong iron spokes cast into hubs or bosses clutched upon the central shaft.

The attendant working the machine stands upon a shelf or platform situated at the front end of the machine, and feeds the tea from the large receiving bin or hopper on the top, to the feeding or cutting roller, after passing between which and the resistance plate it is conveyed or delivered into the upper end of the sorting sieve or cylinder.

The machine is of the following approximate dimensions, viz., 13 feet 8 inches in length by 3 feet 8 inches in width and 7 feet 6 inches in height, and it is capable of sorting in an efficient manner about 800 lbs. of tea per hour into five grades ranging from Pekoe Fannings to Pekoe Souchong, each grade of tea as assorted falling into a box, or any other convenient removable receptacle, through hopper chutes which are arranged directly below the sorting or sieving cylinder, and the tailings being delivered at the rear into another box or receptacle as clearly shown in the illustrations.

A machine with one of the above tea cutting mills combined with a small rotary sorting cylinder is also made by the same firm, this apparatus, which is called a tea cutter and equalizer, being intended for use as an auxiliary to the large sorting machine which has just been described and illustrated; the latter is known as the "Sirocco" sorter.

This small machine is employed in the above connection for

equalizing or reducing the size of the coarse leaf or tailings as delivered from the lower end of the sieving cylinder of the large sorter.

The apparatus for cutting or breaking the tea-leaf is in all particulars similar to that of the large machine, but the sorting cylinder or sieve is in this case of small dimensions, the approximate dimensions of the entire machine being only 6 feet 9 inches long by 2 feet 9 inches wide, and 5 feet 3 inches in height. The sorting cylinder is, moreover, fitted throughout its entire length with only one size of mesh for separating the equalized tea from that which has not been sufficiently cut, and which consequently requires to be again passed through the cutting mill.

In other respects the sorting cylinder is provided with vertical screw adjustment at the discharge end, and is fitted with right-angled driving gear of the same pattern as that of the large sorting cylinder.

It is claimed by Davidson & Co., of Belfast, the makers of this as well as the larger machine, that the coarse leaf on being passed through the cutting or breaking mill of the equalizer can, with a very small percentage of dust, be so reduced in size that eventually it will all sift through the equalizer sorting cylinder or sieve, the mesh of which is arranged to be just slightly smaller than the largest mesh in the sorting cylinder of the large machine, that is to say, that of the Pekoe Souchong, or last section. The result of this will be that, when this coarse leaf has been all thus reduced in size, and has been returned to the large sorter, it will become separated into the five grades provided for in this latter machine, when, if the proportion of the coarse leaf to that of the fine tea already sorted out of the bulk be not unduly large, the appearance and size of each of these coarser assortments will be found quite suitable for blending with the finer grades which have been already obtained, and that without reducing their characteristic qualities to any appreciable extent. Whether, however, this latter blending operation be carried out or not, will, of course, rest with the manager of the factory, whose experience will best enable him to judge as to its advisability or otherwise.

It is recommended by the makers, in the case of large factories, to employ three equalizers in consecutive order, the resistance

plate in each of them being successively set or adjusted closer up to the feeding and cutting roller. By means of this arrangement the coarse tea or tailings from the large sorting machine can

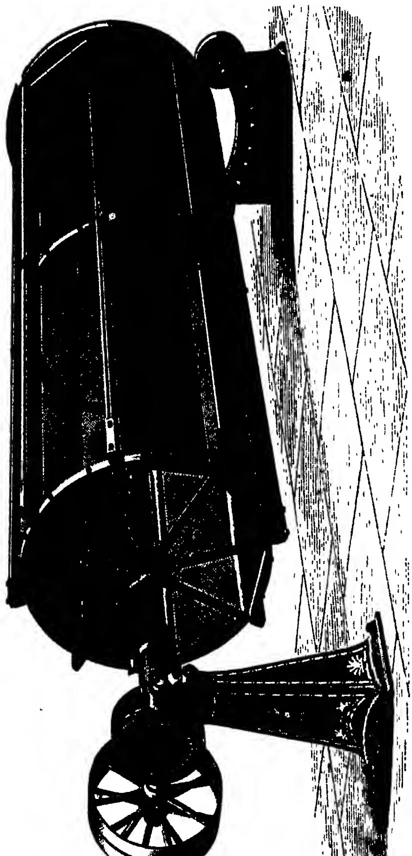


Fig. 132.—Rotary Self-cleaning Tea Sifting Machine (perspective view).

be treated with sufficient rapidity to prevent any accumulation taking place at the discharge or delivery end of the latter.

Three other machines for sorting tea, which are in extensive use, are Jackson's rotary tea sifting machine and combined tea

sorting and cutting machine, and Ransome's shaking tray tea sifter.

The first of these machines is made by Marshall, Sons & Co., Limited, Gainsborough, and is shown clearly in the perspective view, Fig. 132.

This sifting machine is of the rotary type, and is so constructed as to be self-cleaning, which is a considerable advantage, as the chief objection to rotary or cylindrical screens has hitherto been their liability to the curly or twisted leaves becoming entangled in the wire meshes, and thus giving rise to a considerable amount of trouble in clearing them, this operation being usually effected by brushing the screens by hand from the exterior, and any neglect in carrying this out inevitably resulting in an irregular or imperfect classification of the tea.

The framework of the rotary screen is constructed throughout of wrought-iron and pitch pine, and it is so designed as to be both light and strong, the central shaft consisting of a strong wrought-iron tube.

At the driving end, this central shaft is mounted on a massive cast-iron pedestal or standard, having a hinged spherical casing inclosing the driving gear and carrying the fast and loose driving pulleys. This central shaft, moreover, only extends to the centre of the rotary cylinder, the other end being consequently left clear and free for feeding, and an aperture of ample size is provided for that purpose, a disc-shaped baffle plate being fitted, as shown in the illustration, in order to prevent the tea from being accidentally thrown too far into the cylinder by the feeder.

The feeding end is supported on a cast-iron stand, and runs on rollers or pulleys so arranged as to be adjustable vertically, and thus to enable the slope of the cylinder to be suited to the classification of the teas required. It is at this extremity of the screen that the self-cleaning device, which is of very simple construction, is located. This latter consists in the provision, upon the ring or path upon the end of the cylinder, which comes in contact with the supporting rollers, of two trip catches by which the screen has four concussions imparted to it for every revolution, which, it is claimed, has the effect of shaking out the leaves entangled in the meshes.

In order to obtain a thorough classification of the teas, it is

recommended by the makers that one size of mesh wire be used on each rotary screen, except in cases where the teas are not particularly curly, or where they have been equalized before sifting, in which case one-half may be covered with No. 8 mesh, and the other half with No. 10 mesh. The mesh wire has, however, for convenience of transport, in all cases to be tacked on to the cylinder at the factory, and consequently the cylinder may be there covered with such mesh wire as may be deemed the most suitable for the work required to be done by the machine.

The length of this screen is 12 feet, the diameter 4 feet, and the driving pulleys are 24 inches in diameter by 3½ inches width on face, and should be driven at a speed of 70 revolutions per minute.

The combined tea sorting and cutting or reducing machine which has been already illustrated in Fig. 125 is also manufactured by the same firm, and is fitted with the following arrangements of shaking screens or sieves for tea sorting, and two cutting or reducing mills. These latter, which have been already described, are attached to and driven direct by the machine, the uppermost or first one being so arranged as to cut or prepare the tea for sifting, and also to act as a mechanical feeder, and the lowermost, or second one, equalizing the tea that will not pass through the top mesh or sieve, and thus preparing the tea for the market at one operation.

The reducing mills or cutting machines are so arranged that they can be readily thrown out of action, and the sifter or sorting machine worked without them when desired.

The two sorting sieves are removably mounted in frames supported on wooden springs of a tough pliable nature, and have a reciprocating motion imparted to them by a crank and connecting rod, the crank shaft being of steel and bent from the bar without welding, and supported in very long bearings, and the crank end of the connecting rod having a brass bearing adjustable by means of a strap, bolt, and nuts, and all the bearings being provided with efficient means of lubrication to enable long runs to be made.

The sieves are eight feet in length by three feet in width, and ample room or clearance space is left for admitting of both the top and bottom meshes being cleaned. The upper sieve has, of course,

the coarsest mesh, but both sieves are so arranged that they can be readily drawn out and replaced by others of different mesh, thus rendering the apparatus suitable for dealing with different classes of teas, or for various other methods of sifting, which latter feature is one of considerable value.

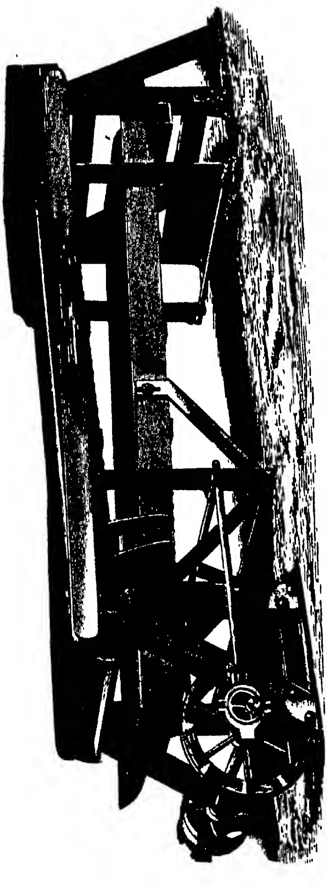


FIG. 133.—Shaking Screen or Sieve Tea Sorting Machine (perspective view).

The machine can be built without the cutting or reducing mills, and used only for the sorting or classification of the teas.

The driving pulleys are 10 inches in diameter by 3½ inches width of face, and should be run at a speed of 265 revolutions per minute.

The Ransome tea sifter or sorter shown in Fig. 133, which is known as the "Simplex," is also of the shaking screen or sieve pattern, and is made by Ransomes, Sims, & Jefferies, Ltd., Ipswich. As its name implies, it is of very simple construction, and is correspondingly low in cost; it is designed to divide the bulk into three sorts of tea, viz.: Orange, Pekoe, and Pekoe Souchong.

The distance from the ground to the top of the feeding hopper being under four feet, this latter is at a very convenient height for feeding in the tea. The sieves of each tray are constructed in two parts, and are interchangeable, so that additional sieves of different mesh can be substituted at any time; as a general rule,

however, the top sieve is fitted with No. 12 mesh, and the bottom sieve with No 9 mesh.

The framing of the machine is made of wood, and the uprights are placed in cast-iron shoes, which is advantageous, inasmuch as they are thus protected as far as possible from the ravages of the white ant.

The requisite reciprocating motion is imparted to the sieves by means of eccentrics upon the driving shaft, the method of connecting the eccentrics to the sieves being perfectly obvious from the illustration, without further explanation.

The position of the driving shaft and the balance wheel provided upon it admit of the machine being operated with great steadiness, the proper speed being 230 revolutions per minute.

The capacity of the smaller size of machine made, which is 10 feet 6 inches in length by 2 feet in width, is from 4 to 6 maunds (320 to 480 lbs.) per hour; and that of the larger sized machine, which is 10 feet 6 inches in length by 3 feet in width, is from 6 to 9 maunds (480 to 720 lbs.) per hour.

Miscellaneous Machinery for Breaking or Cutting, and for Classifying or Sorting the Tea.

Amongst the numerous other machines which have been brought out for breaking, cutting, or equalizing, and for sorting or classifying the tea, are the following:—

A machine for cutting or breaking tea, devised by J. E. Lyndall, consists of horizontal inclined blades attached to a guide, and moved to and fro in a chamber in the casing by means of a crank and connecting rod, by which they are caused to pass through guide slots in one wall of the chamber and work up to its opposite wall. A hopper provided on the top of this chamber admits of the tea being fed into it, whence, after being subjected to the cutting action of the inclined horizontal plunger blades, it will drop upon a sieve below to which a suitable shaking movement is imparted by means of a pivoted lever, actuated by the reciprocating guide carrying the blades, through suitable links.

The flow or discharge of the tea from the chamber can be regulated by adjusting the lengths of the links by which the sieve is suspended, by varying the radius at which the connecting

link is jointed to the pivoted lever, or by means of a check piece or bridge on the sieve.

An arrangement devised by E. Burke consists of placing an ordinary tea-cutting machine beneath the discharge end of a special sifting apparatus, the large tea from the latter falling into the former, and the sieve and the cutting mill being coupled together by chain gearing.

A combination machine for cutting and sifting tea designed by W. Parnall comprises the following essential features:—On a stand or case fitted with drawers is mounted a machine having a honeycombed roller, a knife, a feeding hopper, and a sieve; the roller frame being provided with an aperture through which the roller can be withdrawn and replaced in position.

The hopper is divided by a partition into two compartments, the bottom of one consisting of a sieve which is oscillated by an eccentric, and which discharges such leaf as cannot pass through its mesh to the cutting roller; the other compartment of the hopper feeds the leaf direct to the cutting roller.

The tea to be operated upon is placed in the one or other compartment of the hopper according as it is required to be cut only, or to be both sifted and cut, the siftings passing in the latter case to a separate drawer.

A lift is provided for raising the receptacle containing the tea to the top of the hopper.

Another combination machine is that invented by D. Whyte for cutting and assorting the tea, and for removing any pieces of iron or filings that may be mixed with it.

In this machine the tea is fed through a suitable hopper, in quantities which can be regulated by an adjustable intercepting slide, into a cylindrical vessel having a bottom composed of wire cloth, and in which cylinder is revolved by suitable bevel gearing a vertical spindle carrying horizontal arms covered with wire cloth preferably of a coarser mesh than that of the cylinder bottom.

The tea to be cut will be rubbed between the above-mentioned arms and the wire cloth bottom, falling through the meshes of the latter into a receiver below.

This cylindrical vessel is preferably made in two parts, the upper part or portion bearing upon the wire cloth bottom and

being so arranged as to be adjustable and thus to stretch the latter more or less. The arms are kept pressed upon the tea by a spring or its equivalent, and access can be had to the cylindrical casing or chamber through a suitable door or cover.

In the hopper an arrangement of one or more magnets or magnetized bars fixed in a wooden bar or seat is provided for taking up any iron or metallic dust or filings which may be contained in or mixed with the tea.

In modifications of this machine the rubbing, cutting, or grinding surfaces are made of perforated or honeycombed iron or steel plates, or the cylinder bottom is made of perforated plate and the rubbing arms of wood or metal covered with wire cloth, or *vice versâ.*

The tea can be fed into the machine by hand, the feeding hopper being dispensed with in that case.

In a tea cutting and breaking machine designed by W. Greaves, the tea is caused to fall from a hopper through an opening, the size of which can be regulated by a slide, on to an inclined conductor or chute, by which latter it is conveyed to an inclined rotary screen or sieve through the meshes of which the smaller leaves will pass, whilst the larger ones will be discharged at the end of the screen or sieve to a set of cutting rollers, by which they will be reduced or broken down to the desired size. These rollers have peripheral cavities into which the tea is pressed and broken during the operation of the machine, the rollers being set in close proximity to each other and geared together by means of toothed or spur gearing.

Rotary motion is imparted to the above-mentioned cutting rollers from the driving wheel of the screen through suitable belt gearing.

CHAPTER XII.

PACKING THE TEA.

Old Method of Packing Tea—Machines for Packing the Tea—Wooden Tea Chests and Boxes—Metal Tea Chests and Boxes—Veneer or Compound Wooden Tea Chests and Boxes.

THE old-fashioned method of jolting down the tea into the tea chests by rocking them with levers, and the disgusting practice of treading, tramping, or stamping in the tea, are now becoming obsolete in all well-managed factories and warehouses, and power and hand-driven tea-packing machines are used for the purpose, better grading, less loss, and in some cases from 5 to 8 per cent. more tea, according to the description of tea that is being dealt with, being got into each chest than was formerly possible.

MACHINES FOR PACKING THE TEA.

The advantages of mechanical packing over the old methods consist chiefly of the following:—

Greater expedition in the performance of the work. No pressure of any sort being exerted upon the tea, an absence of broken leaf in the whole-leaf grades, and the formation of a minimum amount of dust. A practically perfect grading of the tea throughout the chests. And, as already mentioned, with some teas the capability of packing considerably more tea per chest than is possible by hand, and as a result the flavour of the tea being better preserved, owing to the leaf being so tightly packed together as to practically do away with all detrimental effects from air percolation.

As regards the latter point, it is usually claimed for machine packing that it enables a larger amount of tea to be got into a chest than could be done by hand packing; but in practice this is not

always found to be the case, as, taking the same description of packing machines working in different districts, it will be found that, whilst in one locality the use of a machine will enable on an average some 10 lbs. more tea to be got into each chest than was possible by hand packing, in another a machine of exactly similar pattern could only be depended upon to get in the exact amount required per chest. This fact is due to certain differences in the leaf in various districts, which are well known to planters.

Of course, the ability to get a larger amount of tea into the chests is a matter of considerable importance, for, besides tending to preserve the flavour of the tea, as above mentioned, it creates a considerable saving in the number of chests required to contain a given amount of tea, and also in the cost for transport from the factory to the port of shipment, and for ocean freights, the freights being usually reckoned by the chest for river transit, and by measurement for ocean transit, and not by weight; and in any case, moreover, there would be the saving of the weight of the chests, and in those of landing, warehousing, etc.

In using a packing machine Mr. Christison recommends the placing of a thin scale at each end of the box or chest, which scales are graduated to, say, eight or some other convenient number of equal parts of its depth to be filled; so that exactly the proportion of the weight to be packed shall occupy the corresponding spaces, neither more nor less, and thus secure an uniform compression of the tea throughout. In this manner, on the one hand, any undue pressure and crunching up of the tea to get all the required contents into the box at the finish will be avoided, whilst, on the other hand, it will prevent the possibility of the tea being packed too tight at first so as to cause it to occupy too little space, and thus leaving the tea too loose at the finish.

The first machines for packing teas were those operating by means of stamps, or a combination of the latter, with a vibrating or oscillating platform, some of which will be briefly described later on, but this type of machine was soon superseded by those working on the oscillatory or vibratory principle only.

A very practical machine, working on the latter principle, has been devised by Davidson and Maguire.*

* Made by Davidson & Co., Ltd., Belfast

Briefly, this machine consists of a table, upon which the chest to be filled is secured between jaws, and this table is oscillated about its trunnions by a crank with or without rotation around a central pin.

In a subsequent improved pattern the pivoted table receives oscillatory motion from a crank shaft through a link and connecting rod, the crank being arranged between and not outside of its bearings, and being driven by an electro-motor. The whole apparatus is mounted on a trolley.

A further improvement was next introduced, which consisted in making provision for keeping the box or chest in a horizontal position during the filling operation.

This object is effected by mounting the table on vertical links and oscillating it about their lower ends, or by connecting the table by means of horizontal links to vertical pins, and oscillating it about them by an eccentric and links, or in another arrangement the table is turned about a vertical pivot beneath its centre.

To facilitate the operation of filling the tea into the chests the table was next fitted with a hopper, in the mouth of which are placed two deflecting plates, so as to cause the tea to fall into the chest in three streams.

This hopper is mounted upon the same bed plate as the rocking table carrying the chest, and consequently receives a certain amount of vibration, which prevents the tea from jamming in the mouth of the hopper.

The most modern forms of the machine are illustrated in the perspective views, Figs. 134 and 135.

The principle upon which this most ingenious but remarkably simple machine works is, as will be readily seen from the drawings, the communication to a platform adapted to receive the chest to be filled of a rapid oscillatory, vibratory, or shaking movement, which causes each successive layer of tea inserted into the chest to settle down into a compact mass without either separating the fine from the coarse leaf, and causing the former to settle or find its way down to the bottom of the chest, or producing dust and broken leaf.

All the packing machines that have been subsequently designed and constructed, or, at any rate, all those that are practically

successful in operation, are constructed on a similar principle, and operate by imparting a vibratory, oscillating, trembling, dithering,

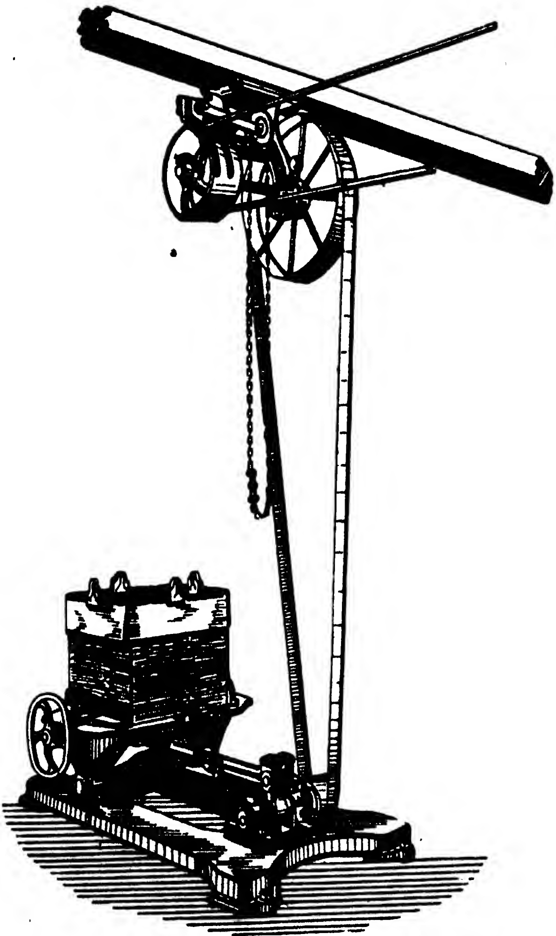


FIG. 134.—Power Tea Packing Machine with Special Countershaft (rear perspective view).

jigging, or like movement to the chest through the medium of some suitable mechanism.

Referring to Davidson and Maguire's machine, the first illustration is a perspective view, showing the tea packer provided with a special countershaft, and the second is a similar view, but taken from the other side, depicting the machine fitted with a feed hopper, but without a special countershaft. The latter pattern may, however, of course, be likewise fitted with a special countershaft when desired.

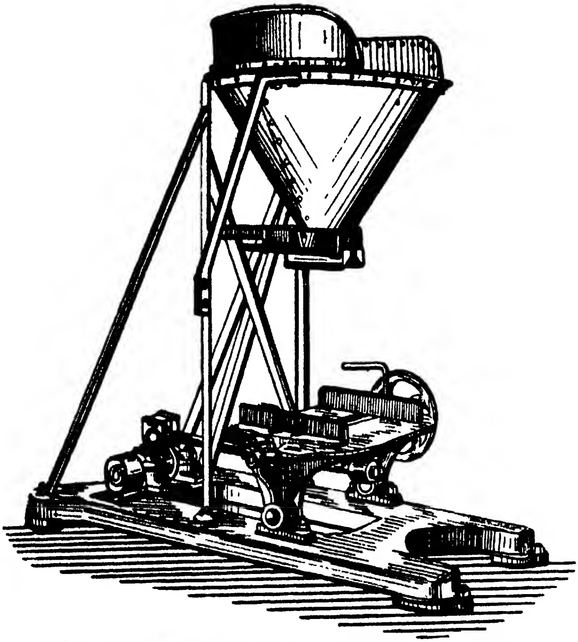


FIG. 135.—Power Tea Packing Machine fitted with Self-acting Feed Hopper (front perspective view).

As will be seen from the illustrations, the platform or platen of the machine is provided upon its upper surface with two side clamping plates, which can be moved to or from each other by means of a screw-threaded spindle, and also with a suitable screw cramp, by means of which the chest to be filled or packed can be firmly secured in position, as shown in the illustration, Fig. 134.

The platform or platen is hinged or pivoted to the bed or base

plate, and has a rapid oscillatory or shaking movement imparted to it, and consequently also to the chest fixed thereon, by a rocking shaft driven at a high rate of speed, either from a special counter-shaft such as that shown in Fig. 134, which has a striking gear operated by a chain, or from any other available source of power.

It is found advantageous to fit the machine with a conical-shaped hopper such as that illustrated in Fig. 135, for filling the tea into the chests.

This hopper, being mounted upon an angle-iron frame attached to the bed or base plate of the machine, will have, so long as the latter is working, a sufficient amount of vibration imparted to it to prevent any tendency which the tea might otherwise have of sticking and choking up the valve outlet or opening, which latter is situated at the lower extremity of the conical hopper.

This opening, moreover, is fitted, as already mentioned, with a valve having distributing blades so arranged as to cause the tea to fall into the chest in three separate streams, and thereby to effect a very even distribution of it, and to insure a rapid packing.

It is furthermore claimed that the use of this hopper insures a perfectly even grade of tea in all parts of the chest, which is a feature of great importance inasmuch as it enables, owing to the tea being perfectly equal in sample throughout the chests, re-bulking in bonded warehouses to be dispensed with, and thus not only saves the cost of that operation but likewise the serious deterioration to the quality of the tea that results from it.

The approximate dimensions of the machine shown in Fig. 134 are: length 7 feet, width 3 feet 8 inches, and height 2 feet; and those of that shown in Fig. 135 are: length 7 feet 7 inches, width 3 feet 8 inches, and height to the top of the hopper 6 feet 2 inches.

One of these machines is capable of filling or packing from twenty to twenty-five chests per hour.

A machine for filling tea into chests, invented by W. W. Beaumont, comprises the following mechanism for shaking or vibrating the table so as to cause the tea to settle down, or become packed in the chests placed upon it for filling.

The table is for this purpose supported on springs or their equivalent, and carries a shaft upon which is placed an unbalanced weight. This shaft is revolved by another shaft through a coupling, and the centrifugal force of the weight causes the table to vibrate.

The chest is clamped on the table by angle irons or jaws, one of which is movable through a screw spindle.

In a machine for filling tea into chests or boxes, designed by N. W. H. Sharpe, the box or chest is fixed on a vibrating table by clamps operated by a screw and wheel. This table is mounted on springs, and is lifted by cams on the working shaft. A hopper secured to the mouth of the chest fixes the edges of the lead lining and prevents the tea from being spilled.

Fig. 136 illustrates a recent pattern of Sharpe's tea-packing machine which is constructed by Richard Moreland & Son, Ltd.,

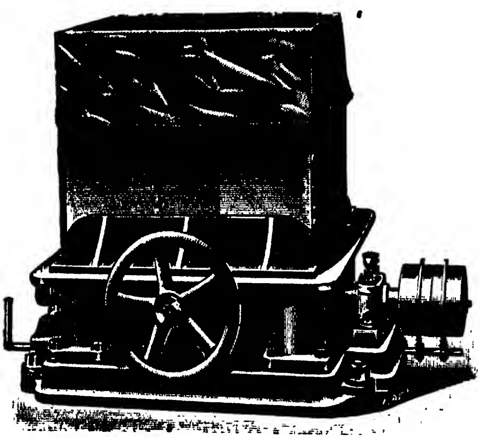


FIG. 136.—Spring Mounted Cam-actuated Power Tea Packing Machine.

London. This machine, which is known as the "Simplex," is very compact and small in size, occupying indeed but little more space than an ordinary tea chest.

The construction of the machine does not differ materially from the first ones designed. Referring to the illustration, it will be seen that the table or platen, upon which the chest is secured by screw-operated clamping plates or jaws, has an exceedingly gentle, and at the same time effective, trembling or vibratory motion imparted to it by being alternately raised and let fall upon spiral springs, by means of an arrangement of cams and rollers. The result of this movement is that, as soon as the belt

is shifted on to the fast pulley, and the machine is put in motion, the cams and rollers will rotate in a noiseless manner, and the vibrations thus imparted to the table or platen being gently intensified by the cushioning or buffing action of the spiral springs, the motion in a short time will become continuous.

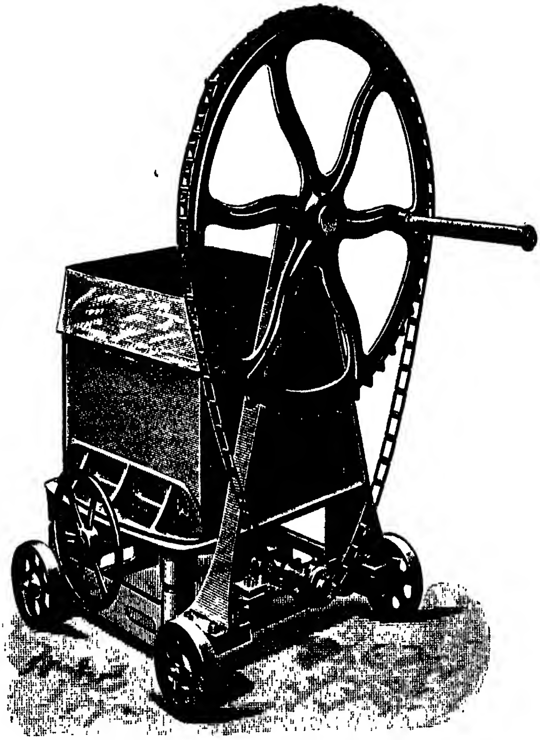


FIG. 137.—Cam-actuated Hand Power Tea Packing Machine.

Amongst other advantages claimed for this packer are the following:—

Owing to the motion that is imparted to the platform or platen being an actual vibratory or tremulous one, and not a rocking one, good results can be obtained with much slower speeds than when the latter is the case, and consequently the countershaft

necessary when high speeds are required can be dispensed with. The moving parts being located directly beneath the table, the strains and torsion to which the machine is subjected when at work are greatly reduced. The comparatively slow driving speed effects a saving in driving power and in the wear and tear of the working parts.

In relation to this latter point, however, it may be remarked that the power required to drive any machine of this description is very small, and that consequently any saving effected in this direction would not form an item of any great importance, more especially as the number of these machines required in a factory is not large.

The machine is fitted with driving pulleys 6 inches in diameter by 3 inches on face, and the speed should be 600 revolutions per minute.

One-sixteenth of a horse power is amply sufficient for driving purposes.

Fig. 137 shows another pattern of "Simplex" tea-packing machine also built by the same firm.

This machine is fitted with Aitken's patent movement, and is arranged to be driven by hand power.

In the first patterns of these hand-power tea packing machines that were constructed, the driving motion used was of a similar type to that employed in the power-driven machine which has been just described. It was found, however, in practice to be somewhat difficult to drive the machine at the requisite degree of speed required to properly pack all grades of tea, and consequently the driving movement shown in the present pattern has been substituted.

Primarily hand-driven tea packing machines were principally designed and built for use in bonded warehouses for repacking tea after bulking, but they are also found to be of great convenience for use in factories where a movable machine, that will enable the planter to pack in any part of his factory, is a desideratum.

The driving gear used in this machine produces, instead of the rapid vibratory motion imparted to the table or platen by the cam shaft employed in the power packers, a dithering motion effected by a succession of short rappings upon the table or platen on which the chest is secured.

The springs used in the other machine are replaced by pins, each of which finds its bed in a cup-like receptacle, and which, instead of being fixed at the four corners, form a tripod on the vibrating table, to which motion is imparted by rollers and cams.

This arrangement insures the weight of the table or platen, and of the chest with its contents, being always in balance, and consequently it reduces the power required for driving purposes to the lowest possible minimum.

Power is transmitted from the hand wheel to the driving or cam shaft by chain gearing, and as the driving shaft need not rotate at a greater speed than 240 revolutions per minute in order to do satisfactory work, the driving handle does not require to be turned at a greater speed than sixty revolutions per minute, thus enabling the machine to be worked by hand-power with facility.

A series of tests carried out with this packer, and extending over several weeks, showed, it is said, the average capacity to be from 30 to 40 chests per hour. And in repacking after bulking at bonded warehouses, the invoice weight of tea was in every case fully repacked, whilst in some instances more tea could be got into the chests than they previously contained. The grading in every case, moreover, was found to be excellent.

Jackson's tea packing machine, which is constructed by Marshall, Sons & Co., Limited, Gainsborough, is shown in Fig. 138.

The special feature of this machine is the manner in which the platform or platen *a*, of the machine, upon which the tea chest *b*, to be filled or packed, is clamped, is mounted on angular bracket-shaped steel springs *c*, without any joints or links.

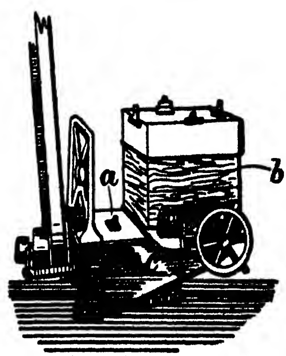


FIG. 138.—Spring Platform Power Tea Packing Machine (perspective view).

To this platen or platform a very fast vibratory motion in a true plane is imparted, a corresponding motion being communicated to the tea in the chest right up to the top until the chest is full.

The construction of this machine is very simple, the moving parts being reduced to a minimum, and there being no complicated mechanism liable to get out of order.

The tea can be packed into the chests by this machine about as fast as it can be filled in by one man.

The fast and loose pulleys are 8 inches in diameter, and the speed should be 750 revolutions per minute.

An apparatus for packing tea into boxes or chests, designed by J. Richards, consists of a combined tea mixing and packing apparatus. The first arrangement will be found briefly described on pages 378, 379, under that heading.

The second or packing arrangement consists in supporting the box or chest, which receives the tea from the mixing machine, on a tray or platform which is alternately brought into contact with and raised from the floor, the motion being imparted, through an arm, and a cam-actuated rocking lever, from a shaft, by pulleys and belting.

The impact resulting from the contact between the tray or platform and the floor is said to compactly settle the tea in the box or chest.

Referring to tea packing machines working either by a combination of stampers and oscillation, or by the action of the former only, the following may be taken as being fairly representative of the class:—

A machine, designed by T. Howard, provides for carrying the chest or box to be filled upon a rocking frame pivoted to a base-plate, and fitted with a handle. A prismatic-shaped weight is suspended from a balanced lever, and serves to both distribute the tea as it is fed into the chest and also to press down the latter.

In order to enable the tea to be weighed after packing, the arms of a weighing-machine are caused to rise and lift the frame from its supports.

A machine for filling tea into chests or boxes, invented by J. Dick, comprises a platform resting on travelling wheels, and supporting another platform on which the chests or boxes are placed, the latter being secured in position upon it by clamps adjustable by means of a left and right handed screw worked by a worm-and-worm wheel through a suitable handle.

Suitable mechanism admits of an oscillating motion being

given to the chests, so that every part of the tea in the chests will be brought under the perforated stamper ends. The arms of these stampers are each formed in two parts, one part passing through a hollow portion or socket on the other. These are so arranged that, as the box gets filled, the stamper will become shorter by the lower arm remaining stationary whilst the upper arm slides over it, a pawl and stop being at the same time swung round out of gear and returned by the action of a spring.

In a subsequent improvement on this machine, the tea is packed into the chest by means of a stamper having a reciprocating movement imparted to it from a disc provided on its surface with a cam groove in which a friction roller on the arm attached to the stamper works. This disc is adapted by means of a groove and feather arrangement to slide on a vertical shaft which receives a rotary motion from a horizontal shaft, thus providing for diminishing the throw of the stamper as the level of the tea rises in the box. A nut and friction rings serve to connect the above-mentioned disc to the vertical shaft with the requisite tightness. The stamper is perforated so as to allow the tea to pass through, and the table supporting the box is mounted on springs. A screw shaft worked by a hand wheel serves to lift the stamper as soon as the chest is filled.

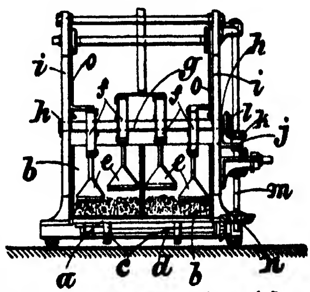


FIG. 139.—Combined Vibrating and Stamp Action Power Tea Packing Machine (front elevation).

Some machines are fitted with two or more of the above-described stampers.

Two machines, devised by Carson and Baildon, both of which operate by a combined jigging or vibratory action to shake down or spread the tea, and a stamping or pressing action applied to the surface of the tea, and uniformly maintained whilst the tea is being gradually filled into the boxes or chests, are shown in Figs. 139 and 140.

In the first of these, a table or platform *a*, supporting the boxes or chests *b*, to be filled, is vibrated by a series of cams,

wipers, or irregular bearing surfaces *c*, mounted on a horizontal shaft *d*, actuated from the main driving shaft through intermediate bevel gearing.

Stamps *e*, are connected by straps *f*, to eccentrics secured upon a shaft *g*, supported in bearings *h*, free to slide or move vertically in guides on the side frames *i*, of the machine. To one of these bearings is secured a bracket *j*, supporting a bevel wheel *k*, gearing or meshing with another bevel wheel *l*, keyed on the shaft *g*. These stamps *e*, are heavy, and two of them are provided to each box or chest, being nearly equal in breadth to the latter, and so arranged that they will be pressed down in succession on the surface of the tea. The upper surfaces of the stamps, moreover, are inclined, so that the tea falling off any one of them will be directed into the box or chest below the adjacent stamp. In the illustration the tea chests or boxes are shown in section so as to allow the action of the stamps to be seen.

The rotation of the eccentric shaft *g*, is effected by a vertical shaft *m*, geared to the horizontal working shaft *d*, through bevel wheels *n*, the bevel wheel *k* being free to slide upon the shaft *m*, but at the same time being forced to rotate with it through a feather-and-slot, or other arrangement, thereby allowing the shaft *g*, eccentrics, and stamps to rise as the boxes or chests become full, and to keep the pressure equal throughout the operation. The unequal filling of the boxes is provided for by fitting the sliding bearings of the shaft *g*, loosely, so as to allow the latter to assume a slightly inclined position.

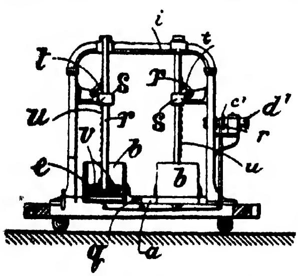


FIG. 140.—Modified form of Combined Vibrating and Stamp-action Power Tea Packing Machine (front elevation).

o are cords for raising and holding in position the shaft *g*, and stamps *e*, during the removal of the filled boxes or chests, and the substitution of others.

In the second arrangement (Fig. 140), cams *c'*, on a shaft *d'*, are connected through levers to a rocking shaft *q*, and thus effect the vibration of the table or platform *a*, which is supported on oscillating arms fitted to this shaft.

A single stamp *l*, is in this latter machine fitted to work in each box, the rod or stem *r* thereof passing through a bearing in a bracket *s*, attached to the frame *i*, and a pawl *t*, pivoted to each of the brackets *s*, engaging with teeth *u*, formed upon the rod, or stem *r*; *v* are apertures provided in the stamps for the passage of the tea, and they are likewise formed somewhat narrower than the chests or boxes, so as to allow of the tea passing round them. The tea chest or box situated on the left-hand side of the illustration is shown in section to admit of the arrangement of the stamp being seen.

Upon the boxes or chests being raised by the vibration of the table, or platform, the stamps will be lifted and retained in that position by the pawls *t*, the tea passing round and under the stamps as the boxes or chests descend and forming a loose layer, which will be pressed by the weight of the stamps, as the boxes or chests again rise and also lift the stamps, and so on until the packing is completed.

Wooden Tea Chests and Boxes.

Of the chests and boxes used to receive the tea, two kinds are in use, those constructed of wood lined with lead-foil, and those made entirely of metal.

The first of these, or the wooden chests, have outer shells composed of shooks, or small planks, which latter are either made at the factory itself, brought to the factory from neighbouring saw-mills, or are obtained from a distance. Those most in favour come from Japan, it having been found by experience by both planters and merchants that the Japanese tea boxes are both very neat in workmanship, and that, what is of considerable advantage, they are also of great equality in weight.

In India and Ceylon, whenever the situation is such that suitable timber can be obtained in the vicinity, it is frequently converted on the premises, in which case circular saw benches, band saws, and a planing machine should be provided in the factory for working up the raw material into the small boards, or shooks, and the corner-pieces, required for making the outer or wooden shells of the chests. The amount of wood that is required for the purpose will be gathered from the fact that were all the

tea exported in a year from Ceylon alone, packed in boxes and chests, each of 100 lbs. capacity, over a million of these latter would be required, consuming eighteen million superficial feet of planking.

In India simmul is the timber chiefly used, in Ceylon a large variety of woods are employed for the purpose, the following being the principal ones:—Arridda, Badulla, Bakmi, Bomi, Diya-taliya, Etamba, Hal, Hulan-hick, Iriya, Ippatta, Kalamadua, Katu-boda, Katu-imbul, Kekuna, Kina, Kirihiria, Kokoou, Kududawula, Láwulu, Lunu-midella, Maha-badulla, Malaboda, Mugunu, Net-awu, Rukattana, Ruk, Sapu, Tawanna, Tel-kekuna, Tiniya, Ulalu, Urukannu, Wal-billin, Wal-sapu, Wellipenna.

The chief desideratum with respect to timber for tea boxes or chests is that it should be of as light a nature as possible.

The lead-foil for lining the chests is, of course, procured from outside; in the factory, however, it is cut up into pieces of the required dimensions, and soldered together, the fourth side or top, as also the wooden lid, being left off until after the tea has been packed in the chest, when the top piece or sheet of lead-foil is soldered in place, and the wooden lid put on, the upper edges of the sides being planed down if necessary to admit of its fitting flush, and the iron hoopings being fixed in position. The stencilling on each chest of the garden mark, the description of the tea contained in it, and the number of the chest, then complete the operation.

When these wooden chests are used it is essential to employ only thoroughly seasoned timber, otherwise the matter oozing out of the green wood will have a corrosive action on the lead lining, with the probable result of tainting the tea that is hermetically closed up in it.

The measurement of tea chests varies, that of those to hold 90 lbs. of tea being 24 × 19 × 19 inches, and of those to hold 60 lbs. of tea being 22 × 19 × 11 inches, the wood being ⅜ inch thick. A box to hold 14 lbs. of tea measures 12 × 11 × 10 inches, the wood being of the same thickness. The numbers of nails required in each of the chests are 42 and 32 respectively, and in each of the boxes 24. The first-sized chest is that commonly in use in India and Ceylon, and the second in Natal. One coolie will make 40 chests to hold 60 lbs. of tea each, or 60 boxes to hold 14 lbs. of tea each, in a day.

METAL TEA CHESTS AND BOXES.

The metal chests are usually made of steel, and this type was first introduced some years back. Metal chests and boxes, however, were at that time unsuccessful, chiefly by reason of the complication of their construction rendering the putting together of the parts a matter of considerable difficulty.

Of late years, however, an improved pattern of steel chest, known as the "Acme" tea chest, has been devised, which appears to be free, or practically so, from the objections which proved fatal to its predecessors.

An undeniable advantage possessed by a steel tea chest is that one of the same outside measurement as a wooden lead-lined chest capable of containing 90 lbs. will hold 106 lbs., or 16 lbs. more of the same class of tea, and, as has been already mentioned, the ocean freights being charged on the cubical measurement of the chest, and the river transport by the number of chests, the gain derivable from the use of the steel chests will be obvious, inasmuch as 116 lbs. can be forwarded in each of the latter at the same price as 90 lbs. in each of the wooden ones, 16 lbs. being carried in fact free in each of the steel chests.

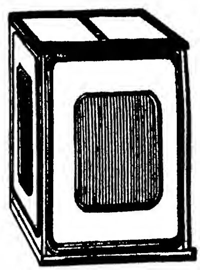


FIG. 141.—Steel Tea Chest or Box.

Moreover, even were the freight to be charged by weight, and not by measurement, the advantage would still be considerably in favour of the steel chest, for the tare of a wooden chest 24 × 19 × 19 inches, or 5 cubic feet, capable of containing 90 lbs. of tea, is 33 lbs., whilst the tare of a steel chest of the same outside measurement, and capable of containing 106 lbs. of the same class of tea, is only 23 lbs., thus again leaving a considerable balance of advantage on the side of the latter.

It is true that the prime cost at the factory of the steel chests is somewhat above that of the wooden ones, the price for those of the size mentioned above being about three shillings and sixpence and three shillings respectively. When, however, the larger number of wooden chests required to contain a given amount of tea is taken into consideration, the cost of these will be found

to total up considerably higher than that of the steel chests; and to this must be added the larger amount to be paid for freightage and warehousing, the amount of saving effected by the carriage of 106,000 lbs. of tea in steel chests of the "Acme" pattern over the carriage of a like amount in wooden chests being £66 13s. 4d., or 1s. 6½d. on every 100 lbs. of tea carried.

In addition to this the tea is said to reach the consumers in a better and fresher condition when packed in the steel chests or boxes than it does when placed in the wooden chests.

Fig. 141 shows the "Acme" steel tea chest as it appears when put together and closed up ready for transport.

Veneer or Compound Wooden Tea Chests and Boxes.

A type of chest and box made of veneer or compound wood has been recently introduced by the Acme Company, which, as regards construction, fixings, and capacity, is in all respects identical with the steel chest. It is, however, lighter in tare, viz., 18 lbs. as against 23 lbs. for a 24 × 19 × 19 inch chest, and is also somewhat cheaper in price. The wood veneer is very thin, not exceeding $\frac{3}{16}$ inch, and strength is attained by making the material 3-ply, each ply crossing the grain of that next to it; the whole being combined with a powerful cement which is said to be proof against damp and unchanged by any climatic conditions.

The above company are said to have laid down extensive plant of a kind quite unique, and have acquired large forests in America growing the peculiar kind of timber required for the purpose of making these chests and boxes.

CHAPTER XIII.

MEANS OF TRANSPORT ON TEA PLANTATIONS.

Roads—Bridges—Portable and Permanent Railway Lines: Rolling Stock—Wagons—Steam Traction—Electric Traction.

ROADS.

THE laying out of the roads on a tea plantation is a matter requiring a considerable amount of skill and judgment, in order to insure their traversing the ground to the best advantage, and of the gradients being of as easy and uniform a nature as possible. In hilly districts the gradients of the roads are generally from about 1 in 7 to 1 in 5, and the width about 5 or 6 feet. The minor roads or paths, however, do not as a rule exceed 4 feet in width, and the gradients not infrequently are as steep as 1 in 3. Badly laid out roads not only cause a large amount of waste of land, but leave many parts of the plantation almost inaccessible.

PORTABLE AND PERMANENT RAILWAY LINES.

On large plantations some method of transport other than porterage must be employed, consequently tram lines, or narrow-gauge railway lines, are usually laid down from the gardens to the factory, the motive power being either animal power, steam power, or electricity.

A method of transportation, and one which would be found especially suitable, in fact the only one possible under certain circumstances, is that by some form of wire-rope or aërial tramway, and this system will be briefly treated of separately in the next chapter.

Bridges.

The laying down of the tram or narrow-gauge railway lines necessitates the construction of a certain number of bridges to carry them across drains, gullies, streams, rivers, &c. These bridges, as also those for carrying the roads across similar impediments, hitherto have been most frequently of a very crude and makeshift character. It would, however, pay in the long run to construct all such bridges of iron, and in a solid and substantial manner, and this is now undoubtedly the practice on all first-rate and up-to-date plantations.

In Figs. 142, 143, and 144 are shown three simple forms of iron bridges such as are commonly supplied by John Fowler & Co., Limited, Leeds, for use in connection with their light railways.

The first of these bridges, or that shown in Fig. 142, is a solid girder bridge which is suitable for spans up to 25 feet in width; the second, or that shown in Fig. 143, is a lattice-girder bridge which can be used for spans of from 25 feet to 120 feet; and the third, or that shown in Fig. 144, is a lattice-girder bridge on iron piers constructed in spans up to 100 feet each. The designs shown are of course only typical of each class, and although, no doubt, they would be found suitable in many instances, on the other hand the requirements in a number of cases would most probably be such as to necessitate certain modifications being made in order to render them available.

Light Railway Lines.

Figs. 145 to 156 illustrate three different systems of the Fowler light railway lines, which would be found suitable for use on tea plantations.

The light permanent line shown in Fig. 145 is constructed with rails weighing either 21 lbs. or 24 lbs. per yard, and usually supplied in 21-foot lengths, with fish-plates and bolts for joints. The sleepers are corrugated and flanged, and are provided with double tongues pressed from the sleeper bar, and clutch bolts. The sleepers are [illegible] three feet apart from centre to centre, and they projec[illegible]ches beyond the gauge line.

The best ga[illegible]se lines are 24 inches and 30 inches.

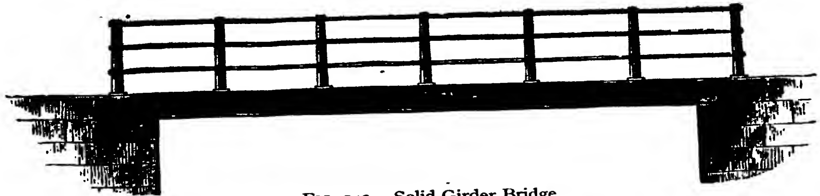


FIG. 142.—Solid Girder Bridge.

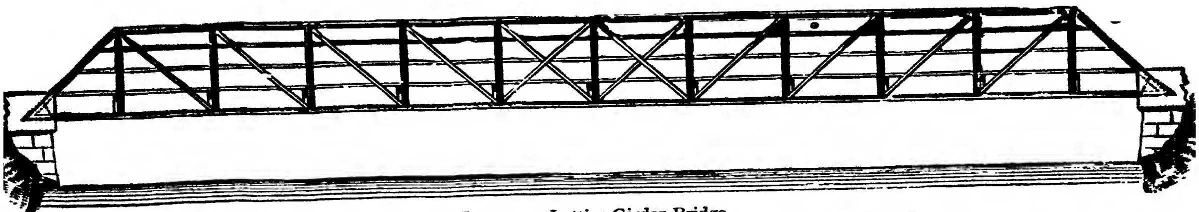


FIG. 143.—Lattice Girder Bridge.

FIG. 144.—Lattice Girder Bridge on Iron Piers.

The description of light railway illustrated in Fig. 146 is constructed with rails weighing either 18 lbs., 21 lbs., or 24 lbs. per yard, generally in lengths of 21 feet, as in the previous case, with fish-plates and bolts for joints, and trough section steel sleepers (as shown on the left-hand side of the drawing), spaced with 3-feet centres, each projecting $7\frac{1}{2}$ inches beyond the gauge line.

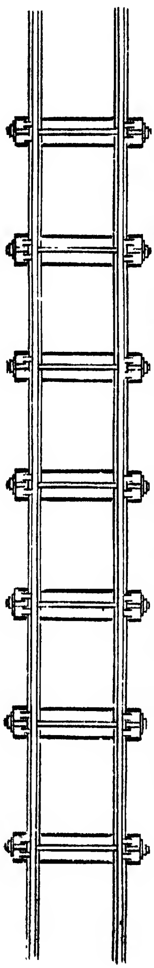


Fig. 145.—Light Permanent Steel Railway with Tongued Sleepers (plan of line).

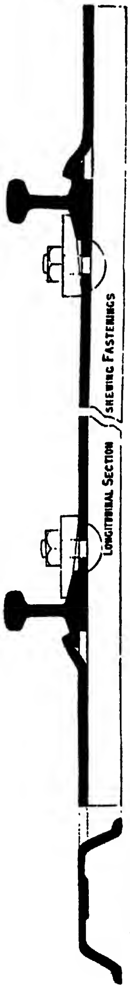


Fig. 146.—Light Permanent Steel Railway (transverse section of line: longitudinal section through sleeper).

The most suitable gauges for this latter line are also 24 inches and 30 inches.

The method of fastening adopted is clearly shown in the right-hand view, which is a longitudinal section through the sleeper or a cross-section of the line.

When desired the joints may be made as shown in the illustration, Fig. 147, which it will be seen consists of fish-plates riveted to one end of the rail, and of a base or sole plate riveted to the opposite end so that the rails dove-tail together and are supported by the sole plate, the fish-plates serving the purpose of keeping the ends fair.

The line illustrated in Figs. 148 and 149, which is constructed with rails weighing either 21 lbs., 25 lbs., 28 lbs., or 32 lbs. per yard, and in the same lengths as those previously described, would probably

form, in the great majority of cases, the best type of Fowler light permanent railway for tea plantation work.

Fig. 147.—Light Permanent Steel Railway (perspective view showing method of jointing).

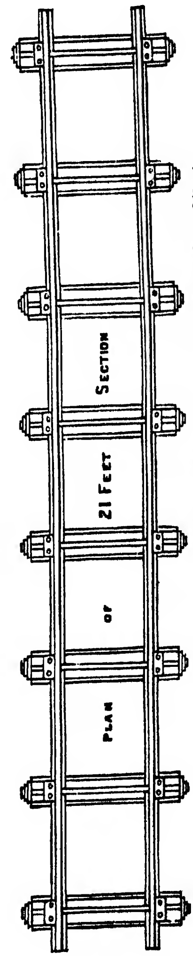


Fig. 148.—Light Permanent Steel Railway with Riveted Chairs (plan of line).

The rails have fish-plates and bolts for joints, and corrugated and flanged steel sleepers with riveted chairs and clutch bolts. The sleepers are 6 inches in width, and of the form in transverse

section shown in Fig. 149, which possesses the advantage of adapting them to bed themselves firmly in the ground, giving an ample bearing surface, and imparting great strength and stability to the track. The sleepers may advantageously be spaced 2 feet 9 inches from centre to centre, each projecting $7\frac{1}{2}$ inches beyond the gauge line.

FIG. 149.—Light Permanent Steel Railway (transverse section through sleeper).

The best gauge for this line is one of 30 inches, but the system can be used up to metre gauge, or 39·37 inches.

Figs. 150 and 151 show respectively a single inclined plane branch, and a diamond crossover with inclined planes.

The first of these can be used for throwing off a temporary branch at any point, and at any angle, to the main line without disturbing it. To enable both the main and branch lines to be worked concurrently, a crossing should be laid upon the main line with an inclined plane at each end. The second shows a method of bridging over the main line at any desired angle without disturbing it. In this case the cross-lines, it will be seen, are laid up to the main line, and a straight section is placed across it with the ends resting on the cross-line, and inclined planes are connected to the ends as shown.

Fig. 152 illustrates a switch-box for a locomotive power crossing; Fig. 153, a two-way switch crossing; and Fig. 154, a three-way switch crossing. The standard radii of these crossings for locomotive power are 45, 60, and 100 feet, and for animal power, 18, 24, and 30 feet.

The Decauville (Decauville, Ainé, Petit-Bourg, France) light railway system is one which would also be found suitable for use on tea plantations.

The rails are, in this system, machine-riveted or bolted to the sleepers, which are of steel, and of channel section, with open or closed ends, in lengths of 16 feet 5 inches. The fish-plates and the base or sole plates are bolted and riveted to the rails so as to form a hybrid junction, and admit of the curves being used in either direction. The above type of line can be either fitted with open-ended sleepers, or with closed-ended sleepers, the latter pattern having the advantage of holding the ballast under the sleepers, and offering a greater resistance to lateral displacement.

These lines are constructed of both portable and permanent

FIG. 150.—Light Permanent Steel Railway (Single Inclined Plane Branch).

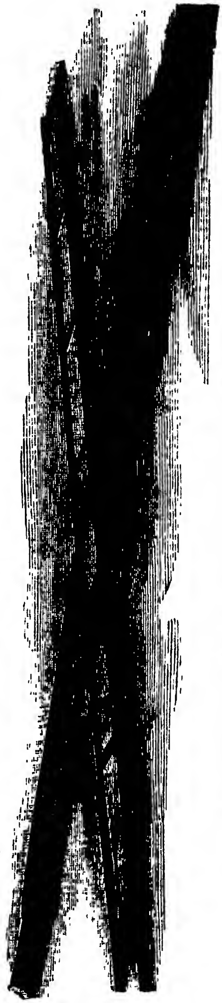


FIG 151.—Light Permanent Steel Railway (Diamond Crossover with Inclined Planes)

patterns, the latter for any load per axle from two tons up to five

and a half tons. About the most suitable description of lines for use on tea plantations would be either one with eight open, or one with eight closed ended steel channel sleepers riveted or bolted to each length of rail, the sleepers being in each case 5½ by 1⅛ inches, and the steel rails 20 lbs. per yard, and of a 24 or 30-inch gauge.

Both these lines are capable of carrying 3 tons 10 hundredweight per axle under ordinary circumstances, and about 30 per cent. more on good ground.

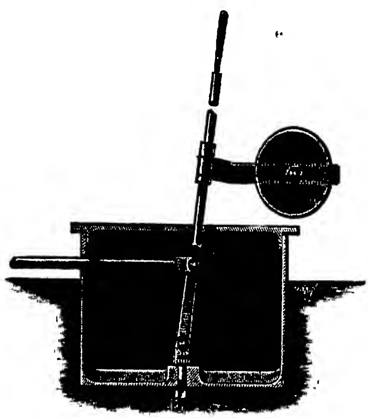


FIG. 152.—Light Permanent Steel Railway (Switch Box for Locomotive-power Crossing).

Crossings and switches riveted to dished channel steel sleepe ready for laying and complete in all details can also be ha For instance, crossings to left or right, arranged for insid movable points; crossings to left or right, arranged f inside fixed points; crossings to left or right, arranged f outside kick-over switches; and outside kick-over switche These crossings are constructed entirely of steel to any radiu and are supplied, when desired, with switch throw-over levers a switch box.

Also plain or wheel-rutted turnplates.

Curves constructed to any required radius can also

obtained ready riveted in sections to steel sleepers, and supplied

FIG. 153.—Light Permanent Steel Railway (Two-way Switch Crossing or Points).

FIG. 154.—Light Permanent Steel Railway (Three-way Switch Crossing or Points).

with base (or sole) and fish-plates similar to the straight sections, these curves being capable of being used in either direction.

For special curves, where the rails must be bent to the desired shape on the spot, a rail-bending apparatus known as a Jim Crow will be necessary.

The operation of laying a line on this system is one of great simplicity. The ends of two sections are placed together on the surface of the ground, which latter usually requires no special preparation. The fish-plates, two of which are firmly attached to the one end of each rail of a section, will then act as guides, and in the case of a portable line for loads up to a ton will form a lock between the heads of the rails and the baseplates, thus

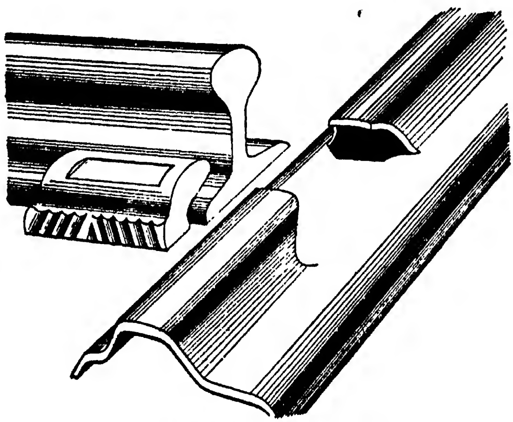


FIG. 155.—Light Steel Railway (views showing method of securing Rails to Sleepers).

producing a joint of sufficient rigidity to preserve the gauge and to enable the line to be used. In the case of permanent lines such as those of the kind mentioned above as being suitable for use on tea plantations, the sections are bolted together with the fish-plate bolts.

J. & F. Howard, Limited, Bedford, are also makers of light railway plant, which would be especially suitable for the purpose under consideration, and their patented system is illustrated in Figs. 155 to 160. The form of steel sleeper used by them is shown in Figs. 155 and 156, and, as will be seen, is made of corrugated and flanged metal plate calculated to give the maximum amount

of strength with the minimum amount of metal. The rails are secured to the patent sleepers in chairs formed by pressing down a portion of the crown of the sleepers, as clearly shown in the left-hand view (Fig. 155), the parts upon which the rails rest being increased in thickness, and the latter bearing upon the entire width of the sleeper. As these depressions are formed by hydraulic machinery, it will be seen that the exact gauge of the line at all parts is insured, and the rails are very firmly held in place by keys, each of which is serrated or roughened at one side, as shown in the left-hand view (Fig. 155), so as to engage with the portion of the sleeper forming the chair when driven home, any necessity for the use of bolts, dogs, or rivets being thus dispensed with. Fig. 156 shows the manner in which the line is laid; it

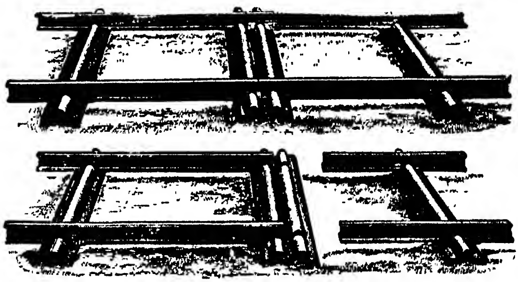


Fig. 156.—Light Steel Railway (plan of Line).

will be seen that the jointing sleepers are made with two corrugations in each of which are formed two depressions, so that the rails abut at the ends, as shown in the upper view, and will be firmly held in their respective chairs or seatings by their toothed keys, either of which latter can be removed without disturbing the other.

It is advisable in all cases to coat the steel sleepers with some suitable anti-oxidation compound.

Where the line is of an entirely permanent character the above described double corrugated jointing sleeper can be dispensed with, and the rails can be jointed by means of fish-plates in the usual manner. In the case of light locomotives the sleepers should be placed three feet apart from centre to centre; for heavier traffic this distance should be reduced by three inches and a stronger pattern of sleeper employed. In the first case there would be

1,760 sleepers to the mile, and in the second case 1,920 sleepers to the mile. The rails are in lengths up to 21 feet, and vary in weight from 14 lbs. up to 40 lbs. per yard, according to the nature of the traffic, the most suitable, however, for the present purpose being those of 22 lbs. or 26 lbs. per yard. The lighter of the above

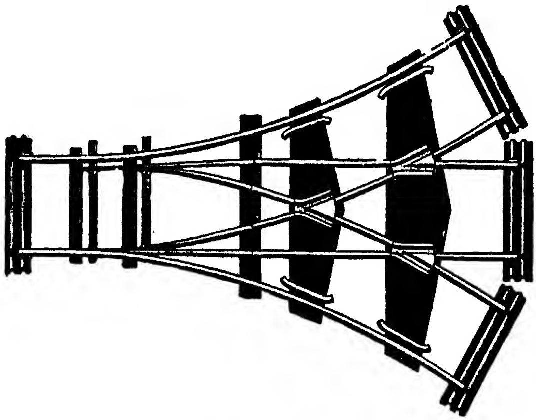


FIG. 157.—Light Steel Railway (Three-way Points or Crossing).

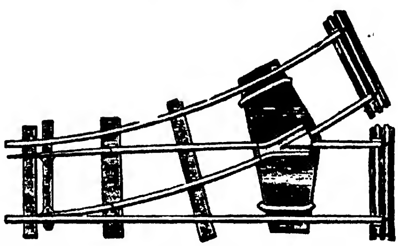


FIG. 158.—Light Steel Railway (Right-hand Points or Crossing).

lines is made of 24-inch or 30-inch gauge, with each sleeper of a length of from 18 to 24 inches over and above the gauge, and the heavier line of 30-inch or 36-inch gauge with the sleeper also of the same length over and above the gauge, the first having an approximate average weight of 53 tons per mile with sleepers, keys, and fish-plates complete, and the second of either 61 or 64 tons, according to the gauge of the sleeper.

Figs. 157 to 160 illustrate points and crossings for use with this type of narrow-gauge railway. The first of these, or Fig. 157, is a set of three-way points; the second, or Fig. 158, is a set of right-hand points; the third, or Fig. 159, is a set of left-hand points; and the fourth, or Fig. 160, is an arrangement of a siding. The sidings consist, as will be seen from the illustration, of a set of either left or right-hand points and crossings, a section of curved

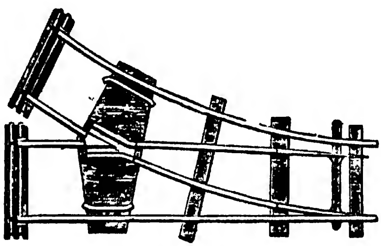


FIG. 159.—Light Steel Railway (Left-hand Points or Crossing

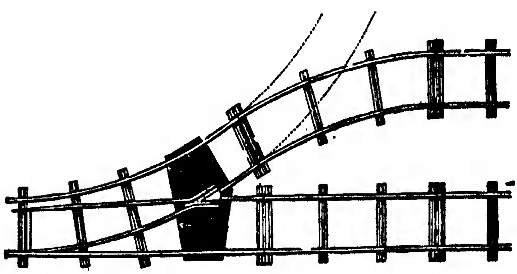


FIG. 160.—Light Steel Railway (arrangement of Siding).

line, and a number of sections of straight line. Pass-byes are composed of a pair of right and left-hand points and crossings, with two curve pieces and the desired length of line between. For locomotive lines the points are provided with levers and switch boxes. Either a right-hand or left-hand single set may be so arranged that a pair of rails may be taken from any part of the straight line, and the points and crossings can be laid in their place without necessitating any fitting.

Curves are provided of 20, 25, or 30 feet radius, or of any special

radius required to suit the wheel base of the locomotive engines. On the main line, however, it is not advisable to have curves of a less radius than 150 to 200 feet if it can possibly be avoided.

WAGONS.

As regards the types of wagons adapted for use on light railways, that illustrated in Fig. 161 is an ordinary wagon to take loads up to three tons, adapted for use on a permanent line where haulage by locomotive power is employed, and it forms one of the numerous types built by John Fowler & Co., Limited, Leeds. Amongst those constructed by the Decauville Company are their ordinary goods wagons, and wagons fitted with wire cages.

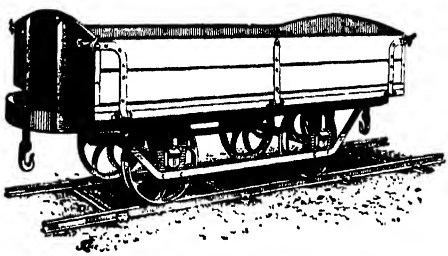


FIG. 161.—Ordinary Light Railway Wagon for Loads up to Three Tons.

The ordinary goods wagon is 13 feet in length by 4 feet in width, having a metal platform, wrought-iron angle uprights, and hardwood body 2 feet 2 inches in height, and is provided with one spring and one dead buffer. It is mounted on two channel iron bogies having wheels 12½ inches in diameter and fitted with oil axle boxes.

The wagon provided with the wire cage has a frame 5 feet 8 inches in length, mounted upon wheels 12 inches in diameter, and fitted with oil axle boxes. The tipping box is of the double wrought-iron equilibrium type, and when provided with the wire cage it is capable of holding 90 cubic feet. It can be used as an ordinary side-tipping wagon by removing the wire cage.

STEAM TRACTION.

For haulage purposes either steam or electricity may be used. When the former is employed, a narrow-gauge four-wheeled

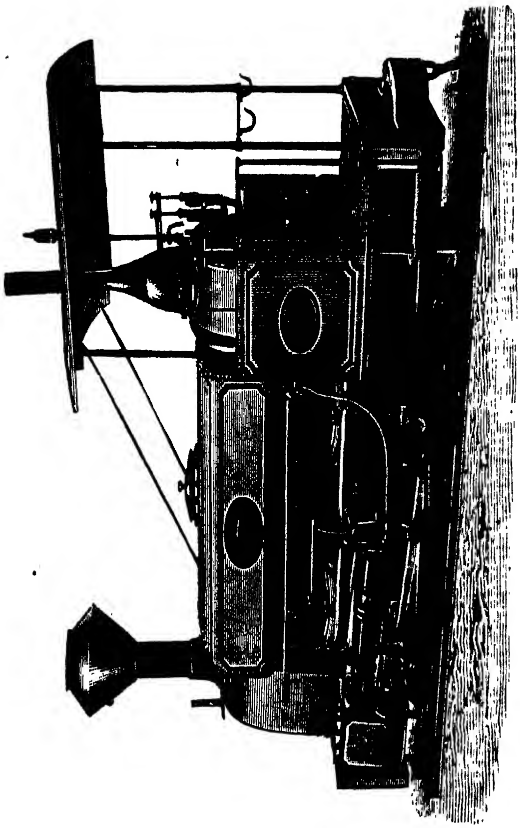


FIG. 162.—Narrow Gauge Four-wheeled Locomotive.

locomotive, such as that shown in Fig. 162, which is built by John Fowler & Co., Limited, would be found suitable. A feature in this locomotive is the increased flexibility which is given to the

wheel base, by which the engine is said to be not only enabled to more surely keep on the metals, but is also rendered capable of hauling a considerably heavier load, and that, moreover, with less strain to itself. The boiler is made of the best mild steel, with either a copper or steel fire-box and brass or steel tubes. The funnel is fitted with a spark arrestor, and, as shown in the illustration, a suitable shelter or cab is provided for the driver.

A fuel tender, either especially constructed to carry wood fuel, or for coal, and if desired also made to serve as a water-tank, is constructed for use with this locomotive.

The minimum radius of curves required for this locomotive is one of 50 feet.

The Decauville four-wheeled narrow gauge (24 and 30 inches) locomotive and tender weighs when empty 4 tons 18 cwts., and, when fully loaded, 6 tons 1 cwt. It is fitted with a fire-box for burning coal or wood, cab for driver, American pattern funnel, two injectors, and two lamps.

The boiler is adapted to work at a pressure of 170 lbs. per square inch. The total heating surface is $93\frac{1}{2}$ square feet, and the capacity of the water tanks is 132 gallons. The cylinders are $5\frac{7}{8}$ inches in diameter by $11\frac{3}{16}$ inches stroke, and the wheel base is 3 feet $3\frac{3}{8}$ inches, the minimum radius of curves being 50 feet.

The mean service speed of the locomotive is 9 miles per hour, the consumption of fuel being 14 lbs., and that of water $10\frac{1}{2}$ gallons per mile. The load which it is capable of drawing on the level at 6 miles per hour is 70 tons, and at 9 miles per hour 60 tons. On a gradient of 1 in 200, the haulage capacity at the above speeds is respectively 45 tons and 38 tons; on one of 1 in 100, 32 tons and 27 tons; on one of 1 in 66, 25 tons and $20\frac{1}{2}$ tons; and on one of 1 in 50, 20 tons and 17 tons.

Electric Traction.

In localities where water power is available, and indeed in other cases, electricity might be employed with considerable advantage as a motive power on the narrow-gauge railways, and in cases

where water power is available for driving the dynamos, and consequently the generation of the electricity could be economically effected, this method of traction would be not only the most convenient but also the cheapest.

Electric traction may be carried out by either direct currents; alternate currents; or by means of accumulators on the locomotive. In the first two cases, the current of electricity may be either carried overhead, on the surface of the ground, or below the surface of the latter.

The only system, however, practically applicable to tea plantations is the trolley system, or that wherein overhead wires deliver the current to the motor on the electric locomotive.

Fig. 163 shows an electric locomotive constructed by the Electric Construction Corporation, Limited. The gauge of this engine is 24 inches, and it is capable of working up to 9 h.-p., which power can be increased for a short time whilst starting a train, or for surmounting a short length of steep gradient. It is capable of drawing a load of 4 tons up a gradient of 1 in 19 at a speed of five miles per hour, can be easily reversed, and is capable of being driven by any ordinary mechanic. The illustration, which has, as well as some of those of rails and sleepers, been borrowed from Mr. Davies's work on "Machinery for Metalliferous Mines,"[1] shows very clearly the locomotive, two wagons, and a portion of the line. In this instance, however, it is being employed for the transport of minerals.

The current from the dynamo at the factory for the generation of the necessary electricity is conveyed through a bare copper wire which is suspended overhead from insulators fixed to horizontal arms or brackets upon vertical poles or standards erected at suitable intervals along the line. The requisite contact between the engine and this copper wire is effected by means of the arrangement shown on the top of the engine, which rubs continually against the wire, adjusting itself as required, to suit any variation in height, through suitable balance weights. An arrangement of switches enables the driver to control the current at will, and, after passing through the electric motor on the

[1] "Machinery for Metalliferous Mines," by E. Henry Davies (London: Crosby Lockwood & Son).

locomotive, the current returns to the dynamo through the rails.

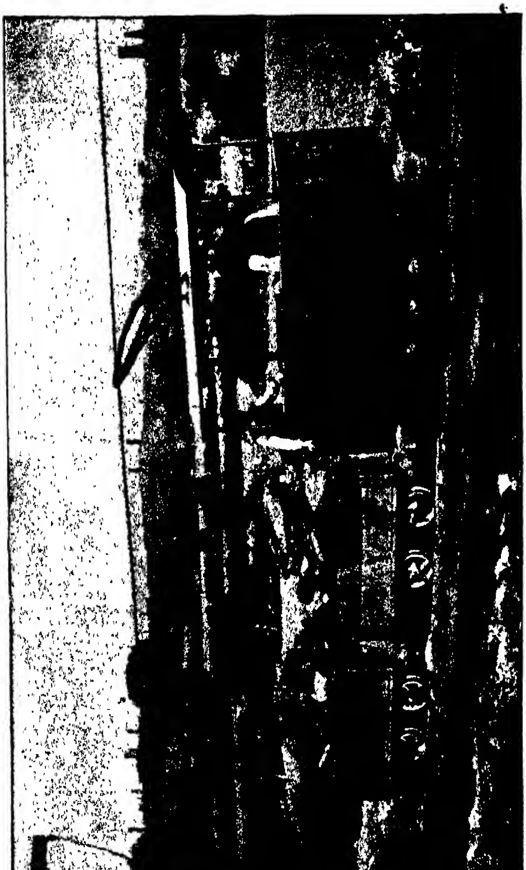


FIG 163.—Electric Locomotive working on the Trolley System.

The arrangement for carrying the electric conductor, or wire, may be of the simplest possible description.

An objection to this arrangement is the possibility of occasional sparking taking place between the conducting wire and the contact-making device on the electric locomotive; but this, although rendering it unsuitable for use on roads in underground workings, such as in fiery coal mines, is of no vital importance in the case under consideration.

The rails must be electrically jointed together by means of a length of copper wire extending across the fish-plates in such a manner as to insure a complete metallic circuit for the return current through the locomotive wheels, and thence along the rails back to the generating dynamo, otherwise no special departure from the ordinary narrow-gauge line, as used for steam traction, is required. In fact, the erection and working of the plant is a matter of great simplicity, and one which can be satisfactorily carried out without the employment of any special skilled attention.

In the next chapter, in which transport by aërial or wire-rope tramways will be found treated of as fully as the space at command will admit, a method of electric traction as applied to that particular system known as telpherage will be dealt with.

The power house or generating station is a matter requiring considerable attention, and to insure its proper equipment several points must be satisfactorily determined, viz.: What is likely to be the maximum demand for power, and how long such maximum power is likely to be required? What will be the average power required? And, finally, at what electric pressure it is required to supply the current to the line?

The main factors to successful working are:—Sufficient boiler power and to spare, when steam power is employed, to provide the necessary supply of steam, and to allow of one boiler being out of work and under repairs. Engines with ample margins of power above that required to drive the dynamos. Generators or dynamos with an ample margin of efficiency over that required to supply the necessary current to the line. And, finally, the provision of a proper distributing and controlling switch-board, measuring instruments, and safety and controlling appliances.

As regards the construction and choice of the dynamos necessary for generative purposes, this matter will be briefly gone into in the chapter on "Miscellaneous Machinery and

Apparatus," when describing an electric light installation for the factory. A brief description of an electric motor will likewise be found in the same chapter under the heading of motive power, and the first-mentioned description will likewise serve to explain the working of an electric motor, as most forms of dynamos are equally applicable for either purpose.

CHAPTER XIV.

MEANS OF TRANSPORT ON TEA PLANTATIONS—Continued.

Aërial or Wire-rope Tramways—Telpherage—Wire-rope Chutes or Inclines.

AËRIAL OR WIRE-ROPE TRAMWAYS.

AËRIAL or wire-rope tramways form a very convenient means of transport on tea plantations, especially where hilly country has to be passed over. There are two main or principal classes of wire-rope tramways, which are subdivisible into five distinct systems or arrangements, that most suitable for use on any particular plantation being dependent upon the nature of the ground to be traversed, and on certain other considerations.

The following brief description[1] of the different systems will enable an idea to be gained of that which is the most likely to meet the requirements of any particular estate.

The two main or principal classes are, first, that wherein a running or travelling endless rope supporting and moving the carriers is employed; and, secondly, that wherein a fixed carrying rope and a light running or travelling hauling rope attached to the carriers by couplings or grips is used. In the latter case, two fixed carrying ropes are sometimes employed.

These two main classes are further subdivisible into five different systems or arrangements, viz.:—The endless running rope with the carriers detachably connected to the rope by means of saddles; the endless running rope with the carriers rigidly

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[1] For a full description of the different systems, and of numerous installations in different parts of the world, see "Aërial or Wire-rope Tramways: Their Construction and Management," by the author of this work (London: Crosby Lockwood & Son).

fixed in position upon the rope; the double fixed rope type with carriers mounted on trucks or runners and detachably secured at predetermined intervals to an endless hauling rope; the single fixed rope type with one carrier drawn from one terminus to the other and *vice versâ* by means of an endless hauling rope; and finally, two fixed carrying ropes with an endless hauling rope by which one carrier is drawn in one direction upon one carrying rope whilst another carrier is drawn in the opposite direction upon the other carrying rope.

When erecting a wire-rope tramway it is imperative to carefully select such an arrangement as will be best suited to the requirements of the situation. The failures sometimes recorded are generally due to makers insisting upon an universal application of one particular type.

The running or endless rope system, which is by far the most simple, was invented by C. Hodgson about the year 1868. It is capable of advantageous application wherever the amount of material to be carried does not surpass 500 tons per working day of ten hours, and the individual loads 6 cwts. The inclines, moreover, should not be steeper than 1 in 3, and the section of the ground should not necessitate a longer span than 600 feet.

The endless running-rope type of tramway consists shortly of an endless wire rope, supported upon a series of pulleys mounted upon strong posts or standards located some 200 feet apart, but with occasional spans of three times that distance, the rope passing at one end of the line round an arrangement of driving gear comprising a 6 or 10 feet diameter drum rotated by steam or other power at a speed of about three miles per hour, and at the other end round a similar wheel or drum provided with tightening gear. The loads are carried in boxes or receptacles hung on the rope (by means of V-shaped saddles) at the loading end, the arrangement being such as to maintain the receptacles and their contents in a state of perfect equilibrium, whilst at the same time admitting of their passing the supporting pulleys.

But one endless running rope is employed, which, it will be seen, forms both the carrying and hauling rope for the buckets. This system has been improved from time to time, both by its original inventor and also by Hallidie, Carrington, and others; but although apparently so simple, and decidedly the cheapest

plan, its successful working is a matter in many instances of so much difficulty that it is being to a great extent superseded by the fixed rope system. It is still, however, pretty extensively used in Northern Spain and America.

The modified arrangement of the running or endless rope system previously mentioned admits of steeper inclines being worked, indeed it may be said that no limit exists to the gradient that can be successfully negotiated. This type of line is specially suitable where sudden and continual changes of level occur, guard or depressing pulleys being easily placed where requisite without interfering with the passage of the carriers, so that the vertical angle of the line can be altered at each support or standard. The driving and tightening gear and endless rope are arranged practically as before, but instead of the carrier saddles riding on the rope, and being retained in place by friction, they are rigidly secured by a steel band or clip, or other arrangement, so that they are fixed in position and must follow the rope, passing round the wheels at the terminals, instead of running on to shunt rails as in the former case. For this reason the driving wheel is usually arranged in the form of a special clip-drum, and the tightening wheel is so formed as to allow the carriers to pass round it with ease. The carrier receptacles are, as a rule, unloaded by striking a catch, so as to either cause the bottom to open or the whole receptacle to capsize or tip up.

The average cost per ton per mile for transport on the running or endless rope system, including renewals of parts and labour, but not fuel, varies from 3d. to 5d. per ton.

The fixed carrying rope system was also devised by Hodgson, and has been improved by Bleichert, Otto, Carrington, and others. It comprises one or two fixed ropes and a corresponding number of light hauling ropes. This plan admits of very wide spans being made without support, and a valley, river, or ravine of 3,000 feet or upwards can be negotiated with ease. Wherever a sufficient fall occurs, and it is required to transport goods or material from the higher to the lower ground, the power of gravity due to the loads can be utilised, in the case of a double fixed carrying rope line, to raise the empty receptacles, and the line worked practically as a self-acting incline. When, on the contrary, the loads are

required to ascend, or the line is practically level, or in the case of a single fixed carrying rope line, motive power must be provided. A small amount of this, however, will only be requisite for working a line on this system, as the rolling load gives rise to but little friction.

As above mentioned, aërial tramways of the fixed-rope type are sub-divisible into three classes. The first, or that in which two parallel fixed ropes are used, upon which carriers are arranged to run, and are drawn along by means of a hauling rope, forms a desirable arrangement in situations where over 500 tons of material is required to be transported per day, and where the individual loads surpass 6 cwts. The inclines may exceed 1 in 2, and the spans 1,000 feet.

It may here be mentioned, however, that the capacity of transport by the former system may be indefinitely increased by grouping the lines where the situation admits of it, an arrangement which obviously possesses the advantage of practically perfect immunity from complete stoppage through breakdown.

Briefly, this type of ropeway consists of two fixed carrying ropes stretched parallel to each other about 7 feet apart, and supported by posts or standards located about 300 feet apart, upon suitable saddle castings. The carrying ropes are anchored at one of the terminals, and are provided at the other with some suitable form of tightening gear. The carrier-travellers or trucks, which are fitted with steel-grooved wheels to fit the ropes, run upon the latter, the receptacles being suspended from these travellers by means of frames or hangers. The carriers are connected by some suitable form of friction or of locking grips or couplings to an endless hauling rope operated by driving gear at one end, and provided with tightening gear at the other end, the usual rate of speed being from four to six miles per hour. On arrival at a terminal, the grips or couplings are automatically released, and the carrier-traveller runs upon a shunt rail.

This type of wire-rope tramway is economical in wear and tear, but somewhat expensive in first cost, and is unsuitable where there are sudden changes in the vertical angle of the line.

The second type of fixed-rope tramway, wherein a single fixed rope and one carrier are used, is the best suited for situations where only moderate quantities of materials have to be carried,

the individual loads being heavy, and the spans long, and the inclines steep.

The arrangement consists of a single fixed carrying rope, upon which a single carrier is mounted through its traveller or truck, and is drawn forward and backwards by means of an endless hauling rope, operated by suitable reversible driving gear at one end, and having tightening gear at the other. The fixed carrying rope is supported on posts or standards placed at intervals of about 300 feet apart, the hauling rope being carried on pulleys fitted with guide bars located in the centre of the standard over which the carrier passes, the standards being so constructed as to admit of the carrier passing through them. The return portion of the hauling rope is carried upon outside pulleys, mounted upon brackets or arms on the standards. The attachment of the hauling rope to the carrier head is made by a pendant so shaped as to admit of its passing under the saddle-transom.

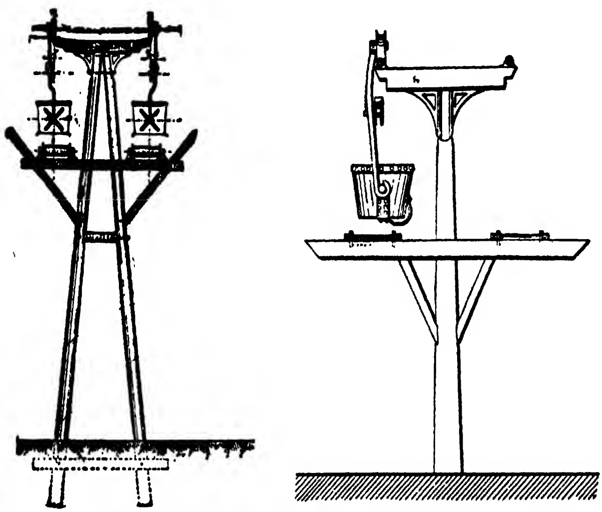
This type of wire-rope tramway is cheaper in both first cost and maintenance than that just described, and it is likewise simpler to erect and to work.

The third type of fixed-rope tramway, in which two fixed carrying ropes and two carriers are employed, the one moving upon one carrying rope whilst the other moves down upon the other, and *vice versâ*, is applicable where the spans are of extreme lengths, and the individual loads very heavy.

The two fixed carrying ropes are stretched side by side, as in the other double fixed carrying rope type of tramway, but only two carriers are used, and most frequently these lines are arranged to operate as self-acting inclines, the loaded carrier descending and hauling up the empty carrier, or lightest loaded carrier, which in turn is loaded and descends. When the loaded carrier passes up, and the empty or light carrier descends, power is used. The travelling speed may be as high as 30 or 40 miles an hour. The individual loads may be of three tons or more, and spans up to 4,500, or even in extreme cases 5,000, feet can be traversed.

This type of line is cheaper than the other arrangement of two parallel fixed carrying ropes in first cost, and also in maintenance, and fewer hands are required to work it. The quantity of material it is capable of transporting per day is, of course, less, and the speed of running produces a rapid wear of the rope.

Whatever system the line be constructed on, the rope or cable must be suitably supported at proper intervals upon wooden or iron posts or standards. These posts are usually placed at from 100 feet to 300 feet apart, the exact distance depending of course upon the configuration of the ground to be passed over, an accurate survey and section of which should be always executed. When, however, a gorge, ravine, narrow valley, or river has to be crossed over, the distance between the uprights or



FIGS. 164 and 165.—Single Wooden Posts or Standards for Aërial Tramway Line.

supports may be very considerably increased, and, as before mentioned, spans of as much as 5,000 feet may be resorted to.

The survey for a line of wire-rope tramway should in all cases be carefully executed. And it is important to bear in mind that wherever it is possible the line should be straight, as each angle will render necessary the erection of a complete station, thus increasing both the cost of construction and that of working. At each point where a post or standard is to be erected the depth of solid ground should be ascertained.

The posts or standards when constructed wholly or mostly of wood may, in the simplest cases, consist of common round

poles or spars forming the legs, and having top cross-pieces of oak or equivalent timber. These legs are stayed near their lower extremities, and should be let into the ground for a sufficient distance to insure their having the requisite rigidity.

Two simple forms of wooden standards or posts are illustrated in Figs. 164 and 165.

Upon the upper ends of the posts are cross-pieces secured in position by iron brackets, and provided with suitable shoes, saddles, or seats, to receive the carrying wire-ropes, two of which are used in both these instances to form double lines. Lower crossbars braced to the posts carry rollers which serve to support the driving or hauling ropes at such times as the latter are not engaged by passing carriers or vehicles.

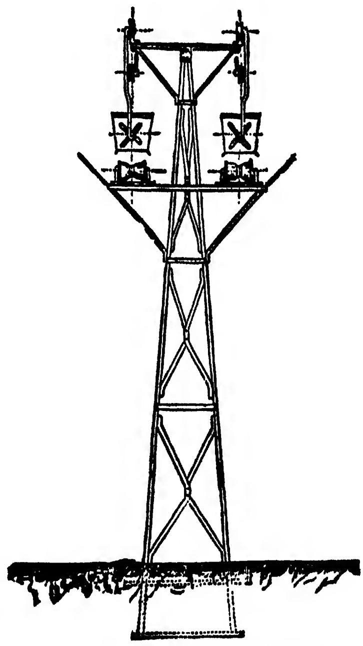


FIG. 166.—Iron Post or Standard for Aërial Tramway Line.

When iron is employed as a material for the supports, channel or I-beams, with angle-iron stiffeners, and channel iron cross-pieces, are usually employed. When the loads are heavy and the spans considerable, moreover, the posts or standards should be constructed with four legs.

The design of these supports, however, whether constructed of timber or iron, will of course vary from those of great simplicity, required for short lines carried at no great height above the ground level, to structures of comparative complexity in the case of the more important installations.

One pattern of iron post or standard is shown in Fig. 166. Another type consists of wrought-iron pipes connected by ferrules, and which can readily be taken to pieces, and adjusted as regards height by sliding the one length of pipe within the other.

The standards or supports, of whatever form of construction they may be, are, when above 45 or 50 feet in height, usually stayed with wire guy ropes as an additional security. When intended for supporting running ropes, the above-mentioned seats or saddles are replaced by sheaves or pulleys.

Space does not, of course, admit of examples of installations on all the hereinbefore-mentioned systems being given, consequently, limitation will be made to a brief description and to some interesting illustrations of a line actually in successful operation on a tea garden, the views being reproductions from photographs taken on the spot, and particulars of a short line will also be found on pages 422 and 423.

The line of wire-rope tramway in question is upon the Gooroo-kelle tea plantation of the Galaha Ceylnn Tea Estates and Agency Company, and is on the Hodgson-Carrington running or endless rope system, wherein the carriers are fixed to the rope instead of being removably connected to it by means of saddles riding thereon. The unloading terminal is shown in Fig. 168, the loading terminal is situated at the other end of the line, at which point the necessary power for driving is also transmitted to the tramway. This line, which is about three miles in length, was constructed upon the fixed carrier system, owing to the steepness of the inclines, some of them being as severe as 1 in 19, and the outline of the ground presenting, as will be seen from the various illustrations, about as difficult a problem to insure successful working as could well be found. The illustration (Fig. 168) shows very clearly the arrangement of the grooved wheel or pulley for carrying the rope, and also that of the tightening gear. The coolie is in the act of unloading the carrier as it passes round the grooved wheel or pulley with the endless rope.

The line was erected for Messrs. Bullivant & Co., Limited, by Mr. Holland Porter, principal assistant to Walker, Sons, & Co., Limited, Colombo Ironworks, Colombo, Ceylon, and the unloading of the carriers was primarily arranged to be effected automatically by the striking over of a catch, by its coming into

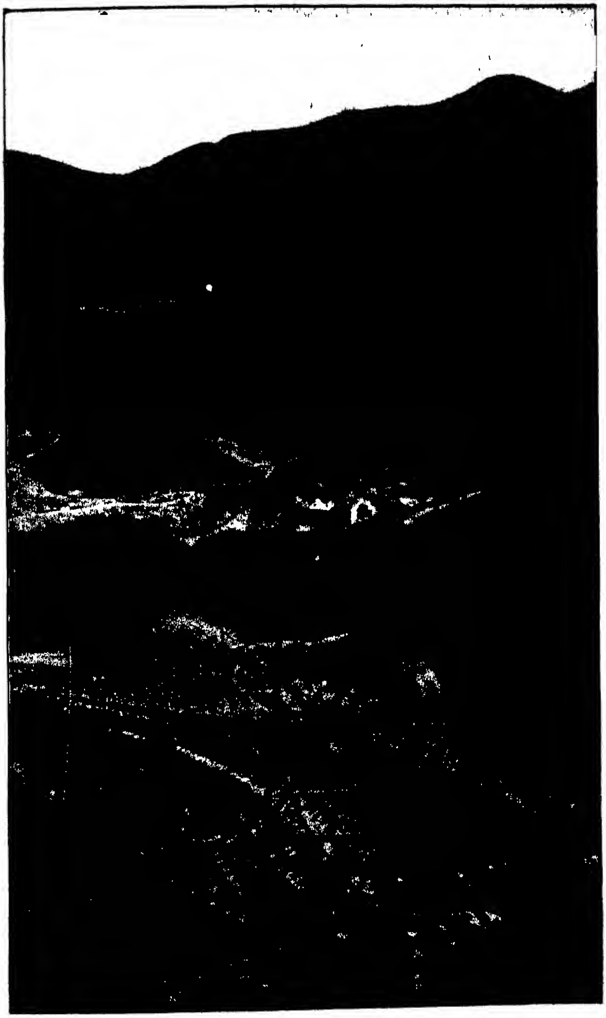


FIG. 167.—Line of Wire-rope or Aërial Tramway on the Goorookelle Tea Plantation, Ceylon (general view of line).

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contact with a wiper, or projection, forming part of the terminal

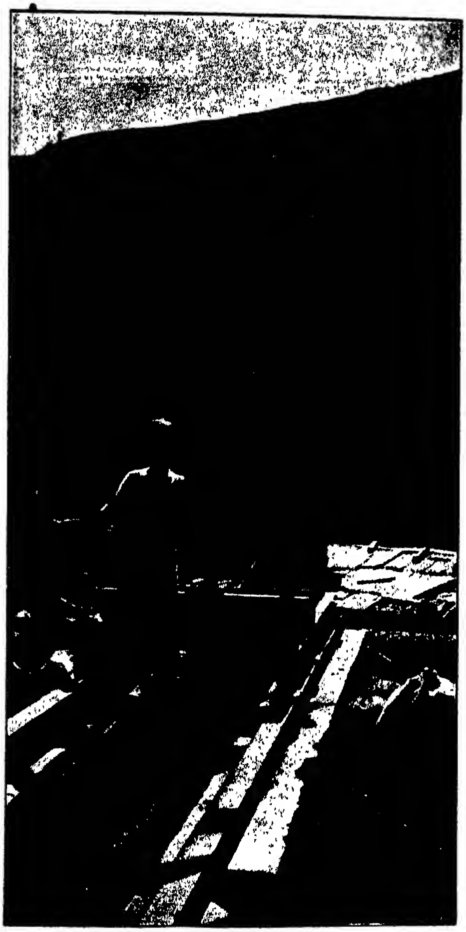

FIG. 168.—Line of Wire-rope or Aërial Tramway on the Goorookelle Tea Plantation, Ceylon (view showing discharging or unloading terminal).

frame. When first put to work, however, this plan was found to be defective, owing to this wiper, or projection, sometimes failing,

by reason of the carrier swinging clear of it through centrifugal action, to knock over the catch, and at others through the catch dropping or falling back into place again before there was time for the load to fall or roll off the carrier. This failure in working of the automatic discharge mechanism was, in all probability, also due, to some extent, to the slackness of the rope or cable not having been taken up, as it should have been, after the line had been in work for a short time. The green or freshly plucked or gathered tea leaf, moreover, being carried in bags in loads of about a maund (80 lbs.) each, is liable frequently to get nestled or shaken down in the carrier, thus further adding to the difficulty of insuring a perfect regularity of automatic discharge.

Fig. 167 is a general view of the line showing the terminal at the factory in the distance. Fig. 168 shows the discharging terminal, the rope being run at a slow speed so that the carriers can be unloaded as they pass the terminal in the manner shown. Fig. 169 depicts the character of the ground traversed, the ropeway ascending the mountain shown in the background, and after passing over it descending to a low level. And Fig. 170 is a view illustrating one of the long spans.

The motive power for use in connection with wire-rope tramway lines may be derived in some cases, where the working conditions permit of this arrangement being used, from the force of gravity developed by the descending loaded carriers. In other instances water, steam, animal, or other power may be employed, and in the case of lines on the fixed carrying rope system more especially, electricity may in some instances be advantageously utilised as a motive power, in which case what is known as telpherage might be advantageously adopted. The most suitable type of motive power and the best method of applying the power to drive the line will, however, naturally be to a great extent governed by the special features of each particular installation. The light line of aërial ropeway suitable for a tea plantation, of which particulars will be found on pages 422 and 423, is an example of one adapted to be driven by animal power.

Wire-rope Chutes.

These, which, as their name implies, consist simply of wire-ropes down which the loads of tea leaf are allowed to run by

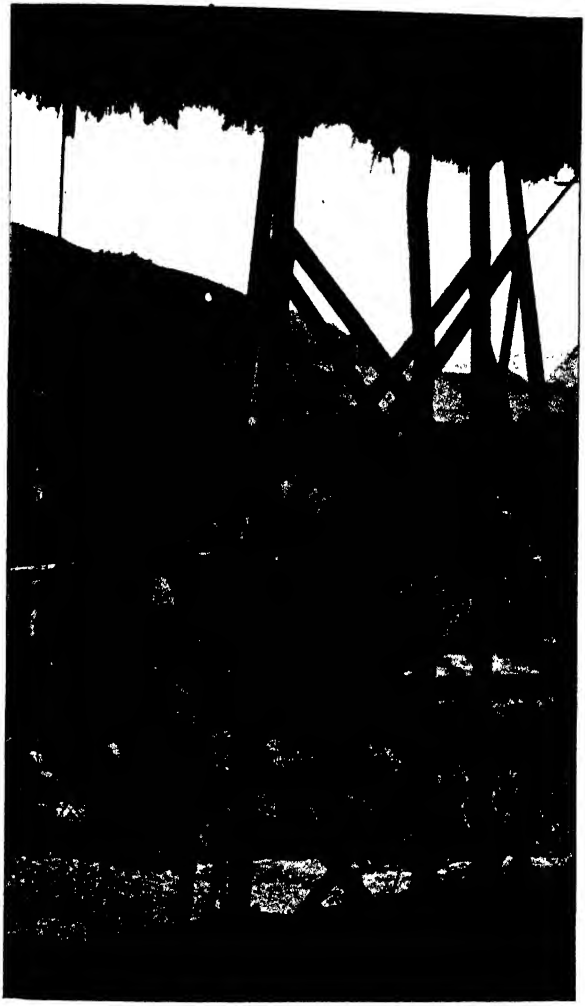

FIG. 169.—Line of Wire-rope or Aërial Tramway on the Goorookelle Tea Plantation, Ceylon (view showing character of ground traversed)

[To face p. 296.

gravity, are used to a considerable extent, on tea plantations, where the outline of the ground admits, and they are found to be both very efficient and economical in operation.

The upper end of each rope is securely anchored, and the lower extremity should be either similarly fastened or secured by means of a pulley block to admit of the slack being taken up when necessary. Only a light rope will be required, and if the loads do not exceed one cwt. steel wire, one inch in circumference, may be used for spans up to about a mile. The carriers are simple affairs, costing only a few shillings each, and from 50 to 100 will be required. The speed can be regulated by increasing or decreasing the sag of the rope, and the shock of the arrival of the carriers at the lower terminal is broken by a heap of boughs, grass, etc. The unloaded carriers are carried back to the loading point by hand, women usually performing this work.

TELPHERAGE.

As regards telpherage, space will unfortunately not admit of entering at any considerable length into a description of this very interesting invention, and those who are desirous of going more fully into the subject the author must refer to his work on "Aërial or Wire-rope Tramways," and to other data upon the subject. The credit of inventing this ingenious system wherein the transmission of the carriers by electricity to a distance is effected independently of any control exercised from the carriers or vehicles themselves, is due to the late Professor Fleeming Jenkin.

The special advantages inherent to the telpher system of driving are as follows:—The conductor being insulated and only connected with the rubbed wire ropeway when a train or carriage is in the vicinity the section of the line behind the train will consequently be incapable of leakage, owing to its not being connected with the dynamo machine, and only the particular section which the train happens to be connected with will be capable of leakage. Another important advantage due to this system of insulation is that, as has been already mentioned, it insures an absolute block system, for say, if, by way of example, a tramway line were supposed to be divided into three sections, and a train be on the second one, no electricity would be given to the first section at all, the current being cut off by the first train on the second section,

and a second train on the first section being by a simple electrical device prevented from getting any electricity until the first train should have left the second section, and in like manner the second train being prevented from getting any electricity on the second section until the first train should have left the third section, and so on, a section being thus always interposed between each of the trains, and the following train being prevented from approaching within a specific distance of the first or leading train.

This action takes place automatically, and no driver is required to the separate trains, which are forced to retain a certain order, and the stoppage of one train will automatically arrest all the following trains at a certain distance from each other, by both removing the source of motive power therefrom, and also by applying very powerful brakes.

The desired block or minimum interval is secured, in this system, by fixing a series of detached insulated wires or other conductors, called block wires, alongside the main conductor. In the simplest arrangement these wires are each of the same length as the sections into which the main conductor is divided, and they begin and end at the breaks in the main conductor. A rubber is provided at each end of the train placing each block wire temporarily in connection with that part of the main conductor which is alongside it. The connection at the leading end of the train will be hereinafter designated the leading cross connection, and the connection at the trailing end of the train the trailing cross connection. The trailing cross connection is a simple wire or other conductor. The leading cross connection includes the coil of an electro-magnet, the armature of which is held down when a current passes, and is released when no current flows, and the movement of the armature when a current passes is made to arrest the train. This electro-magnet will be called the block electro-magnet. This could be effected in various well-known ways; for instance, mechanically, by allowing a break to act; or electrically, as by cutting out the electro-motor on the train, or by short circuiting this electro-motor. These or any other desirable electrical or mechanical actions could be produced directly, or they could be produced indirectly by the help of a relay. So long as one train only be on a given section, the block electro-magnet will remain inoperative, but if the leading end of

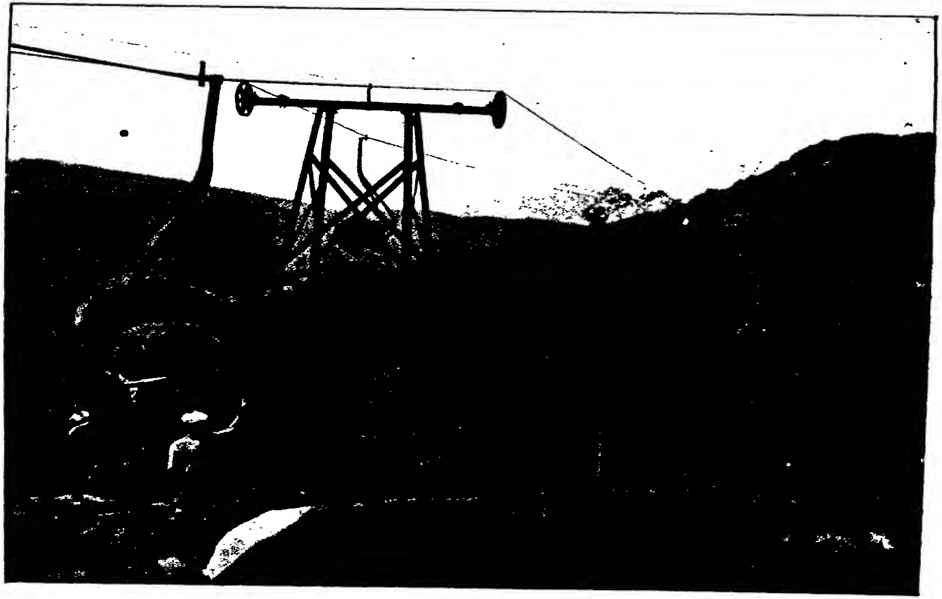

FIG. 170.—Line of Wire-rope or Aërial Tramway on the Goorookelle Tea Plantation, Ceylon (view showing one of the long spans).

[To face p. 298.

a train were to enter on a section still occupied by the trailing end of a preceding train, a derived current would then flow through the trailing cross connection of the preceding train, the block wire, and the leading cross connection of the following train, the electro-magnet of the following train then acting to arrest that train until such time as the preceding train shall have cleared the block wire, when the following train would then be driven as before. This method of blocking is very clearly shown

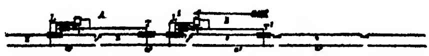

FIG. 171.—Blocking Arrangement for a Telpher Line on the Series System (diagrammatical view).

in the diagram Fig. 171, in which the numerals 1, 2, 3, 4 indicate sections of the main conductor to be connected and disconnected by switches; a^1, a^2, a^3, a^4, the block wires each of the same length as the sections into which the main conductor is divided; A and B two trains; L and L^1 the leading cross connections; and T and T^1 the trailing cross connections. The train B is blocked by the action of a derived current flowing through L^1, a^2, and T.

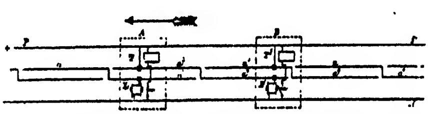

FIG. 172.—Blocking Arrangement for a Telpher Line on the Parallel Arc System (diagrammatical view).

An application of block wires to the ordinary parallel arc system is shown in the diagram Fig. 172. P and N here indicate two continuous conductors, the motor which propels the train being driven by a current passing from P to N by means of rubbers which connect the motor with these rails or main conductors. A and B represent two trains supposed to be driven in this way in the direction shown by the arrow. a^1, a^2, a^3, a^4 indicate block wires which are arranged as shown, and the length of which is not determinate, but which block wires are habitually equal to one another, the first part of one being necessarily equal to the second part of that which precedes it. T, T^1 and L, L^1 indicate the trailing and leading cross connections, and it is obvious that

the train B will be blocked by a current flowing through T, a^2, and L^1. It is usually necessary in each block wire to insert some piece of material such as carbon to prevent the passage of an excessive current.

The simplest method of checking the train is by cutting out the motor on the parallel arc system, and by short circuiting it on the series system, or in the latter system the motor may be cut

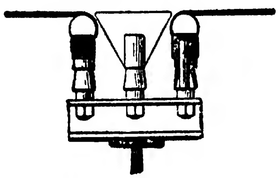

FIG. 173.—Method of Mounting Block Wires in Line on Telpher System (side elevation)

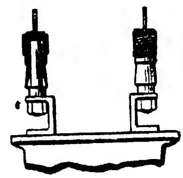

FIG. 174.—Method of Mounting Block Wires in Line on Telpher System (end elevation).

out and the circuit joined up without short circuiting the motor, as shown in the diagrams, and the current may be employed to start a subsidiary electro-motor which puts on a brake which is released when the blocking current ceases, the block being put in

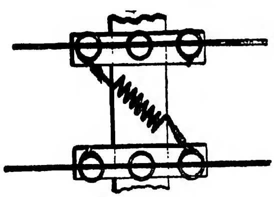

FIG. 175.—Method of Mounting Block Wires in Line on Telpher System (plan).

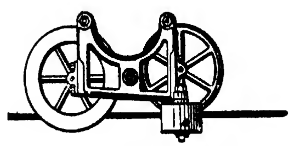

FIG. 176.—Circuit Closer for Telpher Line (side elevation).

action by means of block wires and trailing and leading connections, and no switches, keys, or electro-magnets being used on the permanent way.

A convenient method of mounting the block wires is shown in side and end elevation and in plan in Figs. 173, 174 and 175. In this arrangement metal supports are fixed by the side of the line, on posts or brackets, in any convenient position. Each of these supports carries six vertical pins, and on these pins pottery ware insulators are fixed. The heads of these

insulators are cylindrical, and they are arranged to receive metal caps. To four of these caps the block wires, which are strained between the supports like ordinary telegraph wires, are securely attached. As shown in the illustration, the wire is led down over the curved head of the cap, and is twisted and securely fixed around the body. A cross connection couples two of the wires together, whilst the other two terminate at the support. The contact maker or circuit closer is provided with bearers to lead it without concussion from wire to wire.

This circuit closer takes the form of a carriage, and it is shown in side and end elevation and in plan in Figs. 176, 177 and 178. It consists of metal frames connected by crossbars, and provided with metal wheels which run on the wires, and the

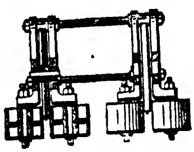

FIG. 177.—Circuit Closer for Telpher Line (end elevation).

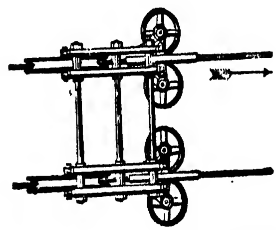

FIG. 178.—Circuit Closer for a Telpher Line (plan).

carriage serves electrically to connect the wires on which it stands. Side rollers are also provided to prevent the carriage running off the wires. A light rod not shown in the drawing forms the connection between the carriage and the train drawn by the electro-motor.

This device connects together the parallel wires on which it stands, which is what is desired in one of the connections. In the other connection, however, it is required that contact should be made with the wires on one side only, and for this purpose the carriage is so made as to insulate its two sides, the crossbars not being fixed directly to the metal side frames, but to insulators like those shown in Figs. 173 to 175, which are carried on vertical pins provided for them upon the side frames.

To regulate the speed at which the train when unchecked will be propelled, that is, to provide means by which the speed

may be maintained constant or adjusted independently of variations in the resistance to be overcome, or in the source from which the electrical energy is derived, or in the circuit, or in the number of trains to be driven by that circuit, without the use of a relay or an electro-motor, the device illustrated in Fig. 179 is employed. A, B, C are three wheels so geared that A will drive B, and if the axis of B remains stationary, B will drive C. If, however, the motion of C be resisted by a force exceeding a given adjustable amount, C will remain at rest and the axis of B will be displaced, an arrangement in fact of differential gearing. C is connected with some resistance such as that due to a fan, a centrifugal brake, a pendulum, or the flow of water through an orifice, so regulated that the resistance will increase with the speed at which the machine to be governed happens to be running.

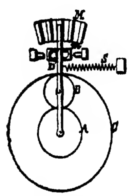

FIG 179.—Device for Regulating the Unchecked Speed of a Train on a Telpher Line (diagrammatical view).

Another resistance is also opposed which may be constant or nearly so to the motion of the axis of B, and to the latter is attached a make and break piece or commutator, or other means of controlling the electrical current supplied to the motor, in such a way that, so long as the axis of B remains at rest, the full driving current will pass through the motor, but when, with the increase of speed, the resistance to the motion of C also increases, and the axis of B moves, this motion will break the circuit, or reverse the connections, or move the brakes, or short circuit the motor, or throw in resistance, in fact the motion of B is used to effect any desirable change in the electrical connections.

Upon the speed decreasing so that the resistance to the motion of C will have again fallen to the normal amount, the axis of B will return to its former position under the action of a spring or weight, by which its motion is resisted, and the current will be supplied as before.

Preferably the axis of B is arranged to move between two fixed stops placed at a considerable distance apart, in order to avoid continual interference with the circuit when running at nearly the normal speed, and the make and break piece attached to B is so arranged as only to alter the circuit when near to either of the two ends of its travel.

Referring to the illustration, A and C are the pitch lines of two wheels externally and internally gearing with the pinion B. A and C are concentric but not on same shaft, or one of them is mounted loosely upon the shaft. B is centred on the arm D which is pulled against a stop by a spring S. A is driven by the motor to be controlled. C is resisted by any resistance which increases with the speed, as by a fan, centrifugal arrangement, or water governor, so that at a certain speed the arm D will begin to rotate round the centre, and will work a make and break piece *m*, or a commutator M, or any other electrical device. The make and break piece *m* may have a slot in it, as shown, so that the pin indicated only moves it to or fro when the arm D is near the end of its travel.

As a rule it is desirable that the change of mechanical resistance to the motion of C should change largely with a small change of speed at the critical point, and a simple plan for effecting this change is by making C drive a brake governor *m* of the type devised by Sir William Thomson, in which a revolving weight is normally clear of an external rim, but at a given speed overcomes the resistance of a spring so far as to come in contact with this rim, and as it were put on a brake by means of the friction it creates.

The effect produced by a governor of the above description is neutralised when the speed of the machine falls back to the normal desired speed or a little below it. Cases arise, however, in which this is undesirable, as some permanent change may occur in the driving current, or in the mechanical resistance to the driven electro-motor, as when the gradient of a telpherage line changes, and this renders a permanent re-adjustment of the electrical mechanism desirable. The simple slot arrangement described above and applied to any centrifugal governor will effect this purpose, or it may be performed automatically and with great accuracy by the governor shown in Fig. 180. A, B, C form a train of wheels so arranged that A drives B, and B drives C, or *vice versâ*, C may drive B, and B will then drive A. Upon B being turned in one direction it produces an electrical change tending to increase the speed of the motor, and upon B being rotated in the reverse direction this change will be undone.

A centrifugal governor is so arranged that when the speed falls below a certain point an arm presses against a smooth pulley or surface connected with A, and so drives B in one direction. When, on the other hand, the speed rises above a certain point, the same, or another arm, presses against a smooth pulley or surface connected with C and drives B in the opposite direction, but when the speed remains intermediate between the two limits, the arm, or arms, are clear of A and C, and B is left at rest. B may thus be employed to shunt or cut out a motor to throw in or out an electrical resistance, or to adjust brushes, or to cause an electric field to apply a mechanical or electrical brake, or to produce any change, mechanical or electrical, which regulates the speed, and in this manner a permanent change may be effected which will not be undone when the motor is brought back to the desired speed. The change may if desired be effected in the driving dynamo instead of in the receiving motor, or in both.

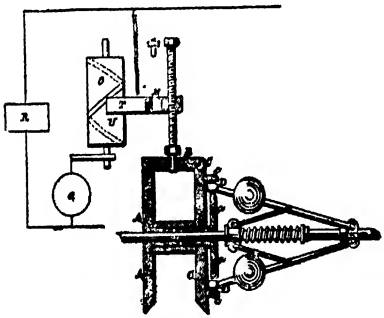

FIG 180.—Governing Arrangement for Train on Telpher System (diagrammatical view).

The governor is preferably employed in the following manner. Connected mechanically with the machine to be controlled is a regulating drum or disc divided into two parts insulated from each other, and a rubber pressing against this drum or disc alternately makes one of two connections. When one connection is made the motor will be driven by the current, but when the other connection is made the current will be diverted or interrupted so as not to drive the motor.

The driving and non-driving connection will be of a length dependant on the position of the rubber relatively to the drum, and this position is shifted in the way above described by the wheels A, B, and C.

In the drawing the rubbing pieces D, D, of the balanced

centrifugal governor, bear against the smooth surfaces *c* or *a*, as the velocity happens to be above or below that required. When the speed is exactly right or normal, these rubbing pieces will run clear, and in the latter case the wheels A, B, C, will all be at rest. If the speed becomes excessive, the wheel B will be worked by C; if, on the contrary, the speed be insufficient, the wheel B will be driven by A. The shaft of B has a screw by which a nut M is worked backwards or forwards and is used to produce the desired change. A desirable method of effecting this required change is shown diagrammatically in Fig. 180. The insulated rubber or brush T actuated by M rubs on the insulated pieces O and U of a cylinder as shown. O is insulated and U is connected by another rubber with one terminal of a motor Q, the other terminal of the motor being joined to a dynamo R, the other pole of which is connected with the rubber or brush T.

It will be seen that if, at one end of the cylinder, the piece U goes all round, and at the other end the piece O goes all round, and at intermediate points the proportions between O and U gradually vary, the time during which the current will be admitted to the motor will depend on the position of the rubber or brush T, which latter will be determined by the governor. The connections for O and U can easily be varied to suit other arrangements in which an absolute break might not be desirable. In fact the well-known system of cutting off the current for a fraction of each revolution is employed, but in such a manner that the cut off shall be undisturbed so long as the speed remains constant, but may be permanently varied by a temporary change of speed so as to be different at different times although the speed may be the same. With this arrangement, if the resistance to the motion of the motor should decrease tenfold below the maximum which the motion could overcome, when the current was on continually, a slight increase of speed would screw M along until the current was cut off for about nine-tenths of each revolution. When the speed had fallen to the desired amount in consequence of the withdrawal of the current, the rubber or brush T would be left in its new position, and the machinery would run at the old speed notwithstanding the great alteration in the conditions.

Fig. 181 shows another arrangement of the governor by which the desired permanent change can be effected, in which a well-known mechanical equivalent is substituted for the three wheels previously used. In this arrangement the bevel wheels A and C are connected by a sleeve, or form part of one piece which is capable of a small motion along the shaft under the influence of a balanced governor, and if running too fast, then its motion will be checked not only by the withdrawal of motive power, but also by the action of a brake.

Fig. 182 illustrates in elevation and section one way of carrying out the above arrangement. The piece M is in this case actuated by the governor so as to move downwards when the velocity

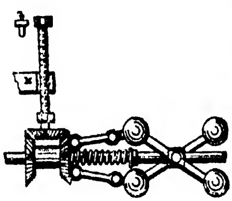

FIG 181 Modified Form of Governing Arrangement for Train on Telpher System (diagrammatical view).

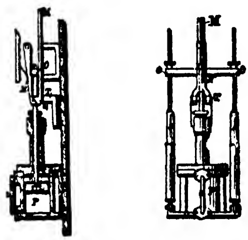

FIG 182 — Brake Arrangement for Trains on Telpher System (elevation and section).

increases beyond the normal; when this motion has reached the limit at which the speed can be controlled, as already described, by entirely cutting off the current, a wedge piece or stop Q will actuate a catch N so as to release the crosshead O. This crosshead will be then pulled downwards by springs, S^1, S^2, its motion being resisted by a dash-pot P, or other contrivance which will delay or retard the motion for the desired time. After the lapse of this time, the crosshead O will fall down nearly to the stop Q, and will make contact at T, so as to apply an electrical brake. The time between the release of the catch and the arrival of the crosshead O at its limiting position, may be for instance 30 seconds, yet when the speed falls, the stop Q attached to M will, as soon as the latter begins to move back again, break the contact at T, and so take off the electrical

brake. On M rising it will again set the catch N. It is obvious that the contact at f may be employed in many ways to arrest the train, indeed the mere mechanical pressure of the springs s^1, s^2, on a quick running wheel, instead of T, would in most cases form a sufficiently powerful brake. The dash-pot P should be so arranged as not to resist the upward movement of the crosshead O, and were a fan employed instead of the dash-pot, it should be driven by the descent of the crosshead O, and not by its ascent.

To enable wire ropes to be used as the insulated conductor, a special form of insulator capable of resisting a great strain, and also of allowing the ropes to rock on the point of support

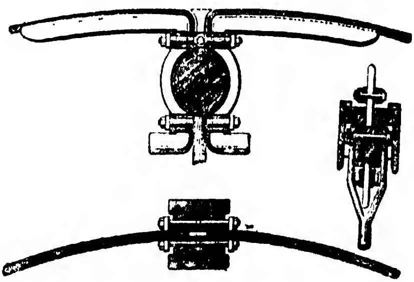

FIG. 183.—Insulator for Use on Telpher Line (side elevation, plan, and vertical cross section)

and so relieve the supports from inconvenient strain, is employed. This insulating device wherein the ends of the wire ropes are secured in bent wrought-iron pieces clipped to a circular insulator free to rotate round a centre pin, is clearly illustrated in side elevation, plan, and vertical cross section in Fig. 183, in which the insulating parts are indicated by cross-hatching.

Horns of metal having shallow grooves on their upper sides intended to receive the wire rope, are bent round the main insulating piece, and again bent back. The rope passes between this metal horn and the main insulating piece, and is also bent back and is secured by being lashed to the horns. The horns are bent as shown in plan when the post is to stand at an angle, and the two horns are clipped together by straps which are insulated from them by insulating packing pieces. A piece

of metal fixed in the main insulator helps to bridge the gap between the ends of the wire ropes.

A pin, which is supported by a fork, serves to carry the main insulating piece, and the surface of the latter near the pin is shielded from the wet by the outer pieces shown in the vertical cross section, and by the form of the main piece itself. The rocking action on the pin prevents any undue strain from coming on the support.

By forming the insulator over the pin in the shape shown, good insulation is insured for the whole system from the earth; and the resistance across the packing pieces is rendered sufficient.

CHAPTER XV.

MISCELLANEOUS MACHINERY AND APPARATUS.

Elevating and Conveying Apparatus — Wood-working Machinery — Refrigerating Machinery — Electric Light Plant — Pumping Machinery — Machine Tools: Motive Power—Steam Engines and Boilers—Oil or Internal Combustion Engines —Water Motors—Wind Motors—Electric Motors.

ALTHOUGH a large proportion of the miscellaneous machinery and apparatus employed on tea gardens cannot be strictly classed as tea machinery, at least if the latter be held to mean only such appliances as are actually used in the dressing or preparation of the leaf, and its conversion from the green state to finished tea, still such machinery plays so important a part, and is so intimately connected with the manufacture, as to call for some notice, premising that, owing to limitation as regards the space at command and by reason of the wide field covered by this auxiliary machinery, the descriptions must be both brief and also be limited to certain representative types.

ELEVATING AND CONVEYING APPARATUS.

In some tea factories where a second fermenting floor is arranged above that on the ground floor, or where the sorting room is located on the second floor, and also in the other departments of most factories, lifts and conveying machinery or apparatus will be rendered necessary. Chutes will also be required for delivering the leaf to the firing or drying machines, etc. The construction of these latter, however, is so simple as to require no particular description. The hoists or lifts may be either worked by steam or by hydraulic

power, or in some cases platforms working in cast-iron guides and connected by chains passing round a drum to a counter-balance weight heavier than the platform, and fitted with a suitable brake, might be employed, or other platform or table lifts adapted to be worked by hand power.

The hydraulic lifts or hoists may be either of the vertical pattern, that is to say with the cylinders arranged vertically, and with tables or platforms fixed to the ends of the wrought-iron or steel piston rods adapted to lift or raise the loads direct, self-acting gear being provided to stop at the highest or lowest points; or they may be of the horizontal pattern in which the cylinder is placed horizontally, and steel-wire rope working over a pulley which can be placed at any required angle is used instead of a piston rod.

The principle on which the hydraulic lift works is analogous to that of the hydraulic press, and is too well known to need any description.

A leaf conveyor and elevator of a type invented by S. C. Davidson, which is shown in Fig. 184, is a very suitable form of apparatus for use in a tea factory for elevating or conveying tea leaf.

This conveying apparatus, which acts upon the pneumatic principle, was originally designed for elevating tobacco leaf from the ground floor to the third floor of a factory, an office which it has been found to fulfil in a most efficient manner, and which no other form of elevator was capable of performing, owing to the delicacy and large size of the leaf to be dealt with, and it has since been found to be no less effective for dealing with tea leaf.

The construction of the conveyor and elevator is of the utmost simplicity. As shown in the drawing, the nozzle of the fan or air propeller passes under the leaf hopper, to which it is so connected that the blast or current of air therefrom will cause an inward suction to take place through the hopper, so that when a basketful of leaf is thrown into it, the leaf will drop through into the blast-pipe, upon which a momentary back-pressure of air will take place, and to counteract this a flap valve which will close under such back pressure is provided in the inlet port from the hopper. In operation, if the leaf be fed into the conveyor in an intermittent

manner, basketful by basketful, this flap valve, after the leaf has fallen past it, and right into the blast current, will be at once automatically blown back so as to close the inlet port until such time as the charge of leaf has attained the momentum of the air

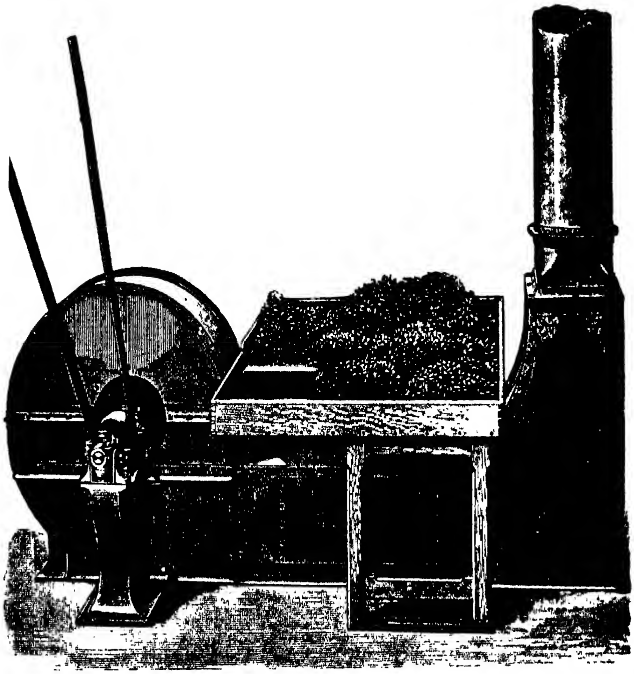

FIG. 184.—Pneumatic Tea Leaf Conveyor and Elevator

blast, which it ordinarily does in less than a second of time, after which the inward suction will again take place, the valve open, and the apparatus be once more ready to receive another basketful of leaf.

If, however, the leaf be fed into the hopper in a continuous manner, and not intermittently, as above-mentioned, this back-pressure does not occur, and the flap-valve will in this case remain inoperative.

This pneumatic conveyor can be very advantageously employed for delivering the green or freshly-plucked leaf from the weighing shed, where it may be emptied direct into the conveyor hopper, out of the pluckers' baskets, or from the receptacles in which it has been transported by the tramway or light railway, or from the bags or other receptacles by which it has been brought to the works by aërial or wire rope tramways, or by means of wire rope chutes, to the leaf rooms, whether these latter be located upon the same ground level or at three or four storeys high, and quite irrespective of the distance to be traversed. If, moreover, the leaf be much stuck together by rain or dew, the blast or current of air by which it is conveyed will effect its separation, and will, besides, carry off a portion of the adhering moisture without in any way tending to injure or damage the leaf.

One of these pneumatic conveyors and elevators is capable of receiving and delivering each basketful of leaf as rapidly as a line of pluckers can pass in single file and empty their baskets into the receiving hopper.

The delivery end of the conveying tube is led into an inclosed compartment in the leaf room, the door of which should have a large ventilating opening covered with wire netting; and when the delivery of the leaf is completed, this door can be opened and the leaf taken away to the leaf or withering racks or chungs.

Wood-working Machinery.

Amongst the miscellaneous machinery required in a tea factory will be a certain number of wood-working machines, which, where the chests or boxes are not made in the factory, may, as has been already mentioned, consist of merely one or two plain or rising spindle circular saw benches for cutting down such timber as will be required for use in repair work, or with the addition, where the wooden chests or boxes are made in the factory, of a couple of hand-saws, and a hand planing and jointing machine, or what would probably be found preferable in many cases, an universal wood-worker.

The wood-working machines, illustrated in Figs. 185 to 191, which are built by W. B. Haigh & Co., Limited, Oldham, would be found suitable for use in a tea factory.

The first of these, or Fig. 185, shows a plain saw-bench with hollow box-pattern frame. This bench is planed perfectly true on the surface of the table, and is fitted with a strong parallel fence so arranged that it can be easily regulated by means of a screw and hand-wheel. The saw spindle is of steel, and is mounted in long and massive gun-metal bearings.

This pattern of plain bench is made in various sizes, the largest 8 feet 9 inches long by 3 feet 2 inches wide, to take in a 48-inch

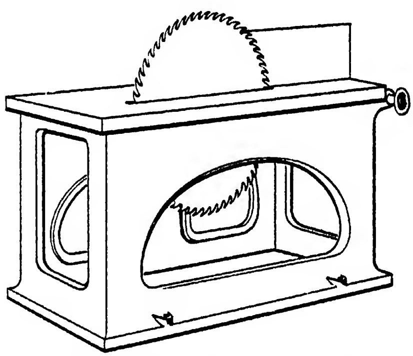

FIG. 185.—Plain Circular Saw-bench, with Hollow Box-pattern Frame.

saw; the approximate weight of this machine is 33 cwts., it is capable of cutting 21 inches in depth, and requires on the average 4 h.-p. to drive it, the size of the driving pulleys being 15 in. × 5 in., and the requisite speed of same being 850 revolutions per minute. The next sizes are, respectively, 6 feet long by 3 feet wide, to take in a 42-inch saw, approximate weight of machine 23 cwts., depth of cut 18 inches, horse-power required 3, size of the driving pulleys 12 in. × 4½ in., and the speed of same 950 revolutions; 5 feet 6 inches long by 2 feet 9 inches wide, to take a 36-inch saw, approximate weight of machine 19 cwts., depth of cut 15 inches, horse-power required 3, size of the driving pulleys 10 in. × 4½ in., and the speed of same 1,100 revolutions; 4 feet long by

2 feet wide, to take in a-26 inch saw, approximate weight of machine 3½ cwts., depth of cut 10 inches, horse-power required 2, size of the driving pulleys 8 in. × 4 in., and the speed of same 1,450 revolutions per minute; 4 feet long by 2 feet wide, to take in an 18-inch saw, approximate weight of machine 6 cwts., depth of cut 6 inches, horse-power required 1½, size of the driving pulleys 6 in. × 3 in., and the speed of same, 2,000 revolutions. The first three sizes are provided with an outer bearing for supporting the off end of the saw-spindle.

In Fig. 186 is illustrated a rising spindle circular saw-bench, made in two sizes, viz., the largest, 5 feet 6 inches long by 2 feet 9 inches wide, to take in a 36-inch saw, the machine weighing, with counter-shaft, 20 cwts., and requiring 3 h.-p. to drive; the driving pulleys are 12 in. × 4½ in., and the requisite speed of the latter 600 revolutions per minute; and the smallest size, 4 feet long by 2 feet wide, to take in a 26-inch saw, the machine weighing, with countershaft, 12 cwts., and requiring 2 h.-p. to drive, the size of the driving pulleys being 8 in. × 4 in., and the requisite speed of the latter 650 revolutions per minute.

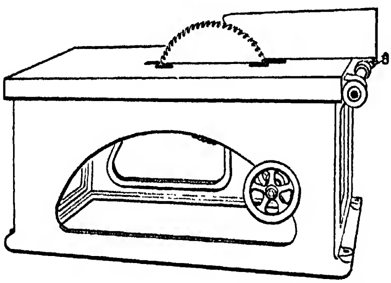

FIG. 186.—Rising and Falling Spindle Circular Saw-bench, with Hollow Box-pattern Frame

The frame of this pattern of machine is similar in construction to the plain bench previously illustrated, and has planed facings to receive all the parts fitting to it. The saw spindle is of steel, mounted in long brass bearings, which latter are fitted into a sliding carriage working on a bracket fixed underneath the table of the machine. This carriage has a rising and falling motion imparted to it by means of a screw spindle which can be operated by the hand-wheel, shown at the side of the bench, through suitable mitre or bevel gearing. The saw-spindle can in this manner be raised or lowered to suit various depths of work to be sawn or bored.

The bench is fitted with a fence arranged to cant for cutting work on the bevel, and is also capable of being turned over the end of the bench, thus leaving the surface of the latter clear for cross-cutting purposes. A suitable stay is provided behind the fence, moreover, which can be used when required, so that any giving of the fence at the end nearest the saw, when cutting deep stuff, a defect to which fences of this description are otherwise liable, may be effectually prevented.

Fig. 187 illustrates an improved pattern of endless band-saw machine, which is made in three sizes, viz., with saw pulleys, 42 inches, 36 inches, and 30 inches in diameter, which are capable of cutting respectively 16 inches, 15 inches, and 12 inches in thickness, and weighing 25 cwts., 20 cwts., and 15 cwts., the sizes of the driving pulleys being 15 in. × 4 in., 14 in. × 4 in., and 12 in. × $3\frac{1}{2}$ in. and the requisite driving speed of same being 250, 280, and 300 revolutions per minute respectively. About 1 h.-p. will be required for driving.

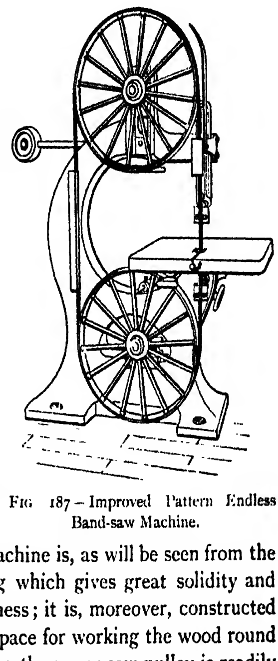

FIG. 187 – Improved Pattern Endless Band-saw Machine.

The frame of this pattern of machine is, as will be seen from the illustration, a hollow box casting which gives great solidity and strength with comparative lightness; it is, moreover, constructed of such a shape as to give great space for working the wood round the saw. The carriage supporting the upper saw pulley is readily adjustable to suit various lengths of saws by means of a hand-wheel and screw, as clearly shown in the illustration, and it is fitted with a tension spring which gives the required elasticity to the saw to take up contraction or expansion whilst at work, and also with an adjustable arrangement to suit saw. The saw pulleys are covered with leather, or, if preferred, with india-rubber, bands, so as to prevent the cutting edge from being worn off, or

the set taken off the teeth, and the bottom pulley works in adjustable brass bearings, the top one having a long boss working on a steel stud pin. The table, which is planed true on its surface and edges, is arranged to cant to any required angle for sawing on the bevel.

A feature in this machine is an arrangement for admitting of the top band-saw pulley being readily canted so as to allow the saw to work on any part of the periphery of the pulleys as occasion may require.

Two band-saw guides are provided, the one, which is made adjustable so as to suit various thicknesses of work to be done, being situated slightly above the table, and the other, which is a fixture, located directly below the table. Each of these guides consists of a bracket carrying a solid steel pulley which receives the back thrust of the saw, and of brass packing pieces which act to guide the saw and to confine it sideways, so as to prevent its twisting when the timber being cut by it is turned round so as to form a curve or sweep.

The guard shown will effectually prevent any injury to the operator should the saw break.

An important point to be attended to in order to insure the efficient working of a band-saw machine is the proper sharpening and setting of the saw-teeth. Especial care should be taken to see that each tooth is set back an equal distance with the rest of the teeth, so that they all may do an equal amount of work. Both these processes can be far more readily effected by means of a very simple band-saw sharpening apparatus than by hand work. An apparatus made by the makers of the above-described machine, consists of a framing constructed out of wrought-iron tubing, and provided with an arrangement for placing the pulleys closer together or further apart so as to suit various lengths of saws. A vice with planed jaws holds the saw firmly in place whilst it is being sharpened or set, and a band-saw setting arrangement is provided by which the teeth may be quickly and accurately set.

A brazing apparatus is also made for use in conjunction with this apparatus which consists of an iron cramp and a pair of tongs. The former is so constructed as to receive the two ends of a broken saw which are held in place by a bracket and thumb

screw, whilst with the heated tongs and brazing wire the piecing is effected. It is of course understood that the ends of the saw to be joined are first suitably bevelled off so as to form a proper scarf joint.

A useful type of machine would be a revolving cutter hand planer and jointer such as that shown in Fig. 188, which can be used for taking stuff out of wind, and also for jointing, bevelling, chamfering, squaring, and many other descriptions of work which are within the capacity of the machine, and which may suggest themselves to the operator. The design of this machine is of an advanced type, the working parts being fixed upon a strong cast-iron column occupying very little floor space, and being so arranged that all the various parts are easy of access whilst the machine is in full operation. The cutter block and spindle are made of steel and are in one forging, and the latter is supported in substantial gun-metal bearings fitted with self-oiling lubricators. The table is made adjustable on angle slides.

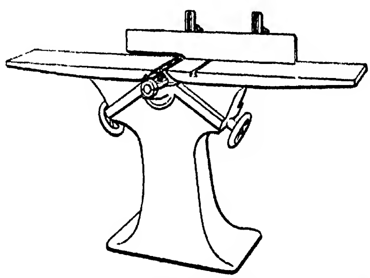

FIG 188.—Small Hand-feed Planing and Jointing Machine.

This pattern machine is made in several sizes, that, however, most generally useful for the purpose under consideration would be the middle one, which is adapted to work stuff up to 12 inches in width. The machine weighs approximately 8 cwts. with its counter-shaft, has a pulley spindle 3½ inches in diameter by 3 inches in width, and the driving pulley on the countershaft is 6 inches by 3 inches on face, and should be driven at a speed of 800 revolutions per minute, The speed of the pulley on the cutter block spindle should be 4,000 revolutions per minute at the least.

To obtain good work from one of these machines it is absolutely essential that the cutters on opposite sides of the rotating cutter block should exactly balance each other, otherwise, if the cutter on

each side of the block be heavier than that on the other, the spindle will be thrown out of balance, thus causing it to spring whilst working, and rendering the work performed by it to be very uneven on the surface, and, in addition to the work turned out being of an unsatisfactory nature, the vibration due to the spindle being out of balance will add very considerably to the wear and tear of the machine. Another matter which should be carefully attended to is the keeping of the lubricators attached to the several bearings constantly filled with oil, as a constant regular lubrication is rendered absolutely necessary by the high rate of speed at which the machine is run, any failure of lubrication being almost certain to result in the bearings seizing and in their speedy destruction.

As regards the proper angle at which to grind the plane irons in order to insure the best results being obtained with all descriptions of wood, this is a matter about which great diversity of opinion exists. It is generally admitted, however, that in the case of cutters intended to be used for working soft wood they should be bevelled back off their cutting edge to an angle of, say, 25 degrees, and for hard wood to one of about 35 degrees, and, bearing this in mind, it will be comparatively easy to sharpen the plane irons, after a few trials, to suit any special description of timber.

It is not, however, by any means an easy matter to sharpen a long plane iron on an ordinary grindstone without the aid of any special appliance, so as to give it the same bevel across its entire width, and it is therefore desirable to employ an automatic plane iron grinder, or at any rate a grinding rest, which can be attached to the frame of an ordinary grindstone, and by the use of which the plane irons can be ground practically true to any required bevel, and that with far more accuracy, and in much less time, than any skilled workman could possibly perform the work by hand. One of these attachments will grind plane irons up to 24 inches in length. Where there is sufficient work for it to be used with economy, an automatic plane iron grinder, however, would of course be found preferable, and it would enable a straight and even bevel of great accuracy to be ground from one end to the other of the knife.

A very useful class of planing machine for box making is the

panel-planing and thicknessing machine shown in Fig. 189, which would be found to be of great service where sufficient work could be insured to keep it usefully occupied.

The framework of this machine is all in one casting, and is constructed of special strength to prevent any vibration or tremulous motion. The edge or cutter block is made of steel and is planed out on two sides to form a back iron up to the knives, and the cutter block spindle is supported in long gun-metal bearings. The feed rollers for passing the stuff over the revolving knives or cutters are made of wrought iron, and their pressure can be readily rendered suitable through the adjustment of strong springs for either light or heavy work. The table, which is planed perfectly true on the top, is fitted with two friction rollers working in gun-metal steps and so arranged as to be adjustable, and capable of being set, to stand slightly above the level of the top of the table, the latter being capable of being raised or lowered by means of a screw operated by a hand wheel, through bevel or mitre wheels, as shown.

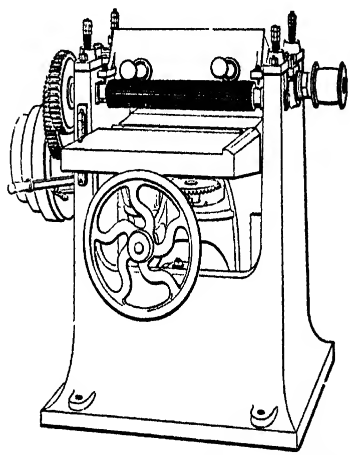

FIG. 189.—Panel-planing and Thicknessing Machine.

This type of machine will plane boards down to $\frac{1}{8}$ of an inch in thickness, and the feed motion can be thrown out of gear instantly. It is made in four different sizes, the smallest being adapted to plane stuff up to 15 inches in width by 4 inches in thickness, and the largest size up to 30 inches in width by 6 inches in thickness, the average power required to drive being from 1 h.-p. for the smallest up to 2 h.-p. for the largest. The speed of the driving pulleys on the countershaft should be 800 revolutions per

minute for all except the largest size, for which it should be 750 revolutions per minute.

The universal wood worker shown in Fig. 190 is another machine of the rotary cutter type which would take the place of any of the other planing machines just mentioned as well as that of a small circular saw bench, and which could besides be employed for effecting much other useful work required about the factory and dwelling houses, such as bevelling, stop-chamfering, striking moulds either straight or irregular, working sash bars, and window bars, tongueing and grooving, boring or slot mortising, etc.

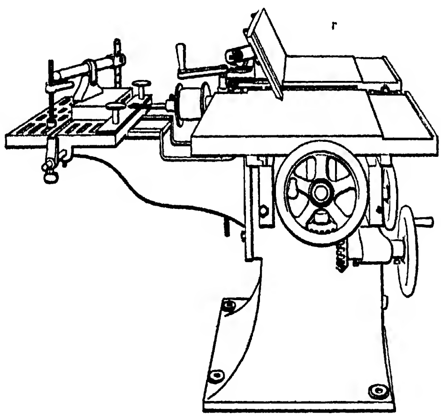

FIG. 190.—Universal Wood-worker with Boring Table.

The construction of the machine is almost sufficiently apparent from the illustration, without the necessity of any further description. The fence is arranged to bevel to any required angle, and the tables are made to rise and fall by means of a hand wheel and screw, and have also a lateral motion to admit a circular saw and moulding or grooving cutters. The spindle will receive a saw 12 inches in diameter for ripping, cross-cutting, tenoning, etc.

A machine of this type will work stuff up to 12 inches in width, weighs with countershaft approximately 14 cwt., requires an average power of $\frac{1}{2}$ horse for driving, the driving pulleys on countershaft being 7 in. × 3 in. and the speed at which they should be run 500 revolutions per minute.

There can be no doubt that for general work a planing machine with revolving cutters is preferable to one with a fixed knife; the former is certainly apt with careless handling, but not otherwise, to leave certain ridges or marks on the timber, whilst the latter, it is true, turns out work with a perfectly smooth surface, the action of the knife being exactly the same as that of the iron in an ordinary hand plane. A great objection, however, to the use of fixed cutter machines is the larger amount of power consumed in driving, owing to the knife being a fixture, and thus offering greater resistance to the timber being pushed over it, and consequently requiring a much more powerful feed motion; and for the same reason machines of this class have to be made far heavier. This naturally applies more particularly to such machines as are of considerable dimensions, and especially to such as are adapted to plane all four sides of the timber at once. Machines having the cutters fitted in a revolving disc are practically obsolete.

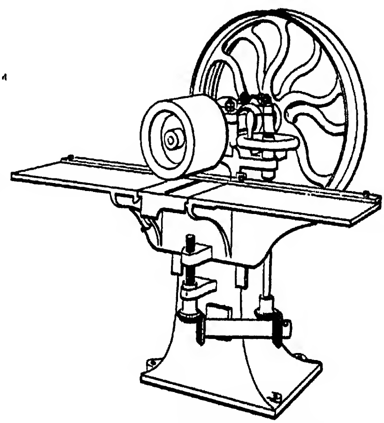

FIG 191 —Fixed Cutter Planing Machine

For light work, however, a fixed cutter planing machine, such as that illustrated in Fig. 191, would be found to be very useful. The stationary knife is fitted in a knife or cutter box fixed in a planed cast iron table, and the stuff to be planed is traversed across the latter by means of a large diametered roller covered on its periphery with indiarubber, and mounted on one end of a horizontal spindle supported in two plummer blocks, as shown in the drawing, and having at the other end two pulleys, 30 in. × 5 in., rotated at a speed of 250 revolutions per minute by means of belt gearing from any available source of power. The work is thus planed as

fast as the hand can place it on the table, and with a finish that cannot be surpassed. The table is so mounted on vertical slides as to be free to move to or from the feed roller, so as to suit various thicknesses of work requiring to be planed, and the necessary adjustment can be made from above the table by means of a suitable hand wheel, which operates through a set of bevel or mitre wheels, and a screwed spindle threaded into a lug upon the table, as is clearly shown in the illustration. The knife box and planing knife are furnished in duplicate so that one of the knives may be sharpened and fixed in place in its box whilst the other one is in use. A convenient sized machine of this pattern would be one adapted to plane stuff up to 9 inches in width, which would have a table 4 feet 4 inches, and would weigh 10 cwts., requiring an average of 1 h.-p. to drive. Box-nailing and box-branding machines might also be employed with advantage.

Refrigerating and Ice-Making Machinery.

In large factories, the provision of a small plant for refrigeration and ice-making is almost a necessity, not only for use in maintaining a proper temperature in the fermenting rooms, more favourable results being obtained at low temperatures than at high ones, but also for providing a sufficient cold storage accommodation for the preservation of provisions with, in addition, sufficient ice-making capacity to supply all the ice that may be required for hospital and other use.

For this purpose the ammonia compression process would be found very suitable, and the description here given will consequently be confined to a small refrigerating and ice-making installation working on this system,* premising with a few remarks upon the suitability of anhydrous ammonia as a refrigerating agent.

Anhydrous ammonia (NH_3) has a molecular weight of 17, and a density of 8·5. This liquid boils at 40° below zero Fahr. at

* For further information on this subject, see "Refrigerating and Ice-Making Machinery: A Descriptive Treatise for the use of persons employing Refrigerating and Ice-Making Installations and Others," by the author of this work (London: Crosby Lockwood & Son).

atmospheric pressure; it has a latent heat of vaporisation of 900, and a vapour tension of 108 lbs. per square inch at a temperature of 60° Fahr. Gaseous ammonia can be liquefied at a pressure of 128 lbs. to the square inch, at a temperature of 70° Fahr., and at a pressure of 150 lbs. at a temperature of 77° Fahr., the pressure required to produce liquefaction rising very rapidly with the temperature. To liquefy by cold, it requires to be reduced to a very low temperature, viz., —85·5° Fahr. The latent heat of ammonia is very great, consequently its value as a refrigerating agent is proportionately large.

The chief advantages derived from the use of anhydrous ammonia as a refrigerating agent are that it possesses greater heat-absorbing power than any of the others at present in use excepting water; that it liquefies at a comparatively low pressure; and that it is neither so deadly in its effect upon animal life as such an agent as carbonic anhydride or carbonic acid gas (CO_2), nor as explosive or inflammable as ether. It must not, however, be assumed that ammonia is perfectly innocuous and safe, and every precaution should be taken to avoid accidents where it is in use. It is a colourless irrespirable gas, having an extremely pungent, peculiar, and easily recognisable odour, and is also slightly combustible when mixed with a sufficient proportion of air, burning feebly with a flame of greenish-yellow hue, and when mixed with about twice its volume of air being capable of exploding with considerable violence. The tendency of ammonia gas, owing to its being only half the weight of air, is to rise when set free, so that there is less likelihood of any person who might chance to be near when an ammonia pipe happens to burst, or a bad leak to take place, becoming overpowered by the gas, than would be the case where carbonic acid gas or carbonic anhydride is used, and in the latter case much higher pressures are also required, thereby adding considerably to the chance of accidents. Should any considerable quantity of anhydrous ammonia become spilt, it is well to remember that it is extremely soluble in water, one part of the latter at a temperature of 60° F. being capable of absorbing some 800 parts of ammonia gas, therefore water should be employed to kill or neutralise it, and any person attempting to penetrate an atmosphere saturated with this gas should not fail to place a cloth well saturated with water over his nose and mouth.

The chief difficulty experienced in the use of ammonia as a refrigerating agent is that ammonia gas, owing to its searching nature, is very difficult to deal with, even at a low pressure; consequently, as may be easily imagined, this difficulty is greatly increased by the comparatively high pressure, or tenuity, that is obtained in a compression machine, which rises in the condenser to as much as 180 lbs. per square inch, which pressure, however, it may be here remarked, is a trivial one as compared to the 1,000 lbs. per square inch required by carbonic acid gas. Leakage of gas at the pump glands, and at other parts of the apparatus, forms therefore the main objection to the use of ammonia as a refrigerating agent, and the means employed to prevent this leakage one of the chief points of difference between ammonia and ether machines.

A further difficulty which is overcome more or less perfectly in various ways in different machines is the liability to an imperfect discharge of the gas from the compressor-pump, and the expansion and consequent back pressure of that remaining therein. Indeed, the most important part of an ammonia machine working on the compression process is the gas compressor.

Space will not admit of illustrating more than one type of machine, and as only installations of comparatively small capacity will be required, the small complete refrigerating and ice-making plant on the ammonia compression system capable of turning out 1 ton of clear block ice per twenty-four hours shown in Fig. 192 will be described.

This plant is constructed by the Pulsometer Engineering Company, London, and the ammonia compressor, which is of the horizontal pattern, is shown in the illustration as driven by a separate engine of the vertical type. The compressor may be driven, however, from any line of shafting conveniently situated for the purpose, or from an oil engine, or any other available source of power. The ammonia pump, or compressor, is of the double-acting type, and to prevent leakage and loss of ammonia gas, the stuffing-box is fitted with a special oil-lubricating arrangement, by means of which a gas-tight joint is secured without any necessity for screwing up the gland so as to grip the rod too tightly, and thus cause an excessive amount of friction to take place. The valves work without any springs or buffers, and being of ample area

reduce the amount of pressure thrown on the pump, and prevent the latter from being overworked.

The condenser is fitted with sets or series of lap-welded tubes which are subjected to high tests, both by hydraulic and air

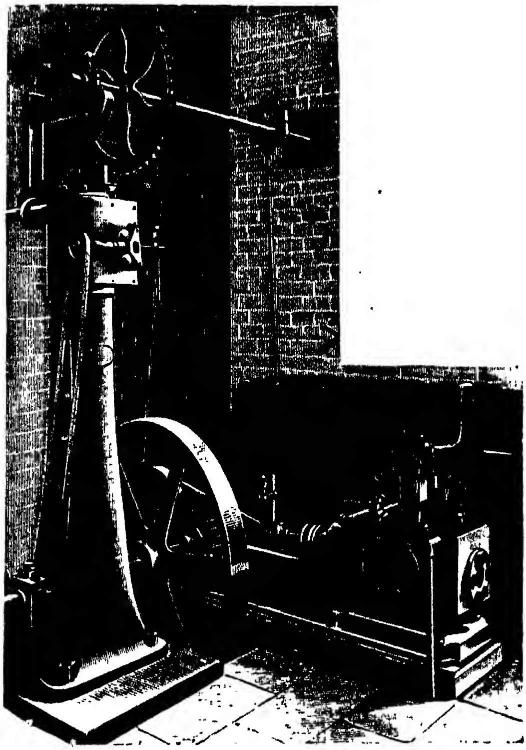

FIG. 192.—Small Installation of Refrigerating and Ice-making Machinery on the Ammonia Compression System.

pressure, and are secured in a patented arrangement of return heads or ends of forged steel. The inlet and outlet valves are likewise made out of forged steel.

The refrigerator consists of a welded steel shell, having hammered steel tube-plates, into which are fitted lap-welded

tubes, also subjected to high hydraulic and air pressure tests. These tubes are so arranged that they can be readily withdrawn from the shell for inspection or renewal, and the whole is fitted in a tank with suitable brine pump connections. The inlet and outlet tubes are also of forged steel.

The advantages derived from the use of sets or series of tubes in the condensers and refrigerators, as compared with that of coils or worms, will be obvious when it is remembered that the latter being usually made in long lengths with a number of welds, should such a tube at any time exhibit signs of weakness, a heavy expense would be entailed to renew it, both on account of the weight of metal, and the difficulty of replacement. In a refrigerating apparatus, moreover, there is an additional disadvantage in that the use of a coil gives rise to a tendency to prime, and thus cause damage to the pump, and there is also considerable trouble in bringing the brine into such intimate contact with the outer surfaces of the tubes as is advisable.

When desired, an arrangement can be fitted to this ammonia compression machine, by means of which the ammonia can be pumped from the refrigerator into the condenser, or *vice versâ*, or, if desired, out of the machine altogether.

The fermenting room may be cooled by means of a series of pipes arranged in it, and through which pipes a non-congealable salt brine previously cooled down to a low temperature in a brine-cooling tank is caused to circulate. When desired, however, the cooling may be effected by allowing the ammonia to expand directly into the series of cooling pipes, or by blowing air into the chamber, which air is first cooled by passing over pipes cooled either on the brine circulation or on the direct expansion system.

For ice-making the can system would be found to be the most advantageous to employ, with or without agitation accordingly as opaque, or clear crystal ice is desired.

The refrigerating chamber, or cold store, may also be cooled on the brine circulation or on the direct expansion system, that is to say, by first cooling a non-congealable salt brine, and then pumping it through a system of pipes arranged in the chamber, or by allowing the ammonia to expand directly into these pipes.

Having now given a brief description of a suitable apparatus, space will only admit, before concluding the subject of refrigeration,

of adding a few general remarks upon the management of an installation on the ammonia compression system.

Previous to starting work the entire system should be thoroughly tested by working the compressor, and permitting air to enter at the suction through the special valves which should be provided for that purpose. It should, if all the joints are properly made, be perfectly tight at 300 lbs. air pressure on the square inch, and should be able to hold that pressure without loss. At the same time that the system is being tested under air pressure it should be also carefully blown through and thoroughly cleansed from all dirt, every trace of moisture being also removed.

Before charging an empty machine with anhydrous ammonia as much as possible of the air contained in the system should be expelled. This can be effected by working the pump so as to discharge the air through special valves usually provided on the pump dome for that purpose.

As it will be found impossible, however, to eject all the air from the plant by means of the compressor, it will be found advisable to insert the requisite charge of ammonia gradually, and not all at once, the best practice being to put in from 60 to 70 per cent. of the charge at first, and cautiously permit the air still remaining to escape through the purging cocks with as little loss of gas as possible, subsequently inserting an additional quantity of ammonia once or twice a day, until all air has been got rid of by displacement, and the complete charge has been introduced into the machine.

To charge the machine, either the dryer, or dehydrator of the apparatus for manufacturing or generating anhydrous ammonia, or where no such apparatus is provided, the drum, or iron, or steel flask of anhydrous ammonia, should be connected, through a suitable pipe, to the charging valve; the expansion valve should be then closed, and the valve communicating with the dryer or dehydrator, or that in the flask or bottle, opened.

Whilst sucking in the ammonia from the dryer, or whilst the flask is being emptied, the machine should be run at a slow speed with the discharge and suction valves full open. In the latter case when one of the steel flasks or bottles has been completely emptied it must be removed, the charging valve having been first closed, and another full flask or bottle placed in position,

the operation being repeated until the machine is sufficiently charged to work, when the charging valve should be finally closed and the main expansion valve opened and regulated. A glass gauge placed upon the liquid receiver will show when the latter is partially filled, and the pressure gauges, and the gradual cooling of the brine in the refrigerator, in cases where a brine circulation apparatus is provided, and the expansion pipe leading to the refrigerator coils becoming covered with frost, indicate when a sufficient amount of ammonia to enable the machine to be started working has been inserted.

It will frequently be found when the ammonia is obtained from steel flasks or bottles, that frost will be formed on their exterior surfaces, with the result that their contents will not be completely discharged, and a loss of ammonia will result. This can be prevented by slightly warming the flasks or bottles whilst their contents are being transferred to the machine.

It is advisable to keep the steel bottles or flasks or other receptacles containing the anhydrous ammonia in a tolerably cool and a perfectly safe situation, and they should be, moreover, moved and handled with the utmost caution and care.

When the machine has been started and the regulating valve opened, it is essential to note carefully the temperature of the delivery pipe on the compressor, and if it shows any tendency to heat, then the regulating valve should be opened wider, whilst on the contrary, should it become cold, the valve in question should be slightly closed, the regulation or adjustment thereof being continued until such time as the normal temperature of the pipe is the same as that of the cooling water leaving the condenser. Should there be an insufficient charge of ammonia in the machine the delivery pipe will become heated, even when the regulating valve is placed wide open.

There are a number of signs indicative of the healthy working of the apparatus, in addition to that of the fact that it is satisfactorily performing its proper refrigerating duty. These signs soon become easily recognisable to those in charge; for example, every stroke of the piston will be clearly marked by a corresponding vibration of the pointers or indexes of the pressure and vacuum gauges. The frost visible on the exterior of the ammonia pipes leading to and from the refrigerator will

be about the same. The liquid ammonia will be distinctly heard passing in a continuous and uninterrupted stream through the regulating valve. The temperature of the condenser will be about 15 degrees higher than that of the cooling water running from the overflow. And finally, the temperature of the refrigerator will be about 15 degrees lower than the actual temperature of the brine or water being cooled.

Air will find its way into the system through leaky stuffing-boxes, and by reason of the improper regulation of the expansion valve, etc. The pressure of air in any considerable volume is shown by a kind of whistling noise, the liquid ammonia passing through the expansion valve in an intermittent manner, a rise of pressure in the condenser, and also loss of efficiency thereof, and by other obvious signs. In this case the air must be got rid of through the purging-cocks in a similar manner to that which remains in the system when first charging the machine.

The presence of any considerable amount of oil or water in the system, which may result from careless distillation, will cause a reduction of efficiency, and will be evidenced by shocks within the compressor cylinder.

The temperature can be regulated by either running the machine at a higher speed, or by increasing the back pressure, or by a combination of both; the back pressure being readily regulated by means of the expansion valve fitted between the receiver and the refrigerator evaporating coils or pipes in the main liquid pipe.

Electric Light Plant.

The value of an installation of electric light in a tea factory, in which much night work has to be carried out, is beyond doubt, the result of the better lighting of the factory being invariably both an improvement in the quantity and quality of the work performed, as skulking and shirking tasks is then rendered a far more difficult matter to effect without discovery.

This is not an appropriate place to enter into any lengthy disquisition upon the use of electricity for lighting purposes, and those desirous of seeking more extended information are

recommended to refer to some of the many excellent works upon the subject which have been written by specialists in this line, such, for instance, as those by J. W. Urquhart.* The following general information, however, may be of use to those about to put up an installation, and unable to obtain the above.

Both the arc and the incandescent systems of electric lighting possess certain distinctive merits, and where the dynamo employed is one designed for that purpose, both these systems can be carried out from the same dynamo at the same time. Arc lamps are suitable for lighting large open spaces, whilst on the contrary, incandescent lamps are those best qualified for the illumination of the interiors of factories. In the first instance a few powerful lamps supported upon tall poles will be required, and in the second a large number of lamps of small power which may be distributed as found to be most suitable to the requirements of each particular case, the best power for these incandescent lamps being sixteen candle power each.

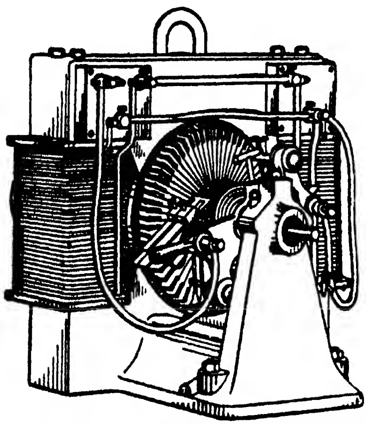

FIG. 193.—Dynamo Electric Machine (perspective view).

The dynamo (Fig. 193) for developing the necessary current of electricity consists essentially of the following parts, viz., a framework constructed of soft cast iron, a field magnet mounted upon the former, an armature arranged in the magnetic field and mounted on a spindle rotatably supported in the above mentioned framework, and finally of a commutator, and of brushes for collecting the electricity from the former. The current is excited

* "Electric Light Fitting," "Electric Light: Its Production and Use," and "Dynamo Construction," by John W. Urquhart, Electrician, published by Messrs. Crosby Lockwood & Son, London.

ı a coil, or, more accurately speaking, in a series of coils of 'ire revolving in the magnetic space or field between the poles f electro-magnets of great power.

The armature consists of a large number of coils of insulated /ire wound over a cylinder formed of soft iron wire, the ends f the coils being fastened to radial copper strips secured to the ıars of the commutator. The brushes are fixed in adjustable ırackets or holders, and should be so arranged as to lightly ouch the commutator tangentially.

When it becomes necessary to move the brushes forward, ıs will be the case after a dynamo has been running for a :ertain length of time, and the electrical balance has become listurbed by heating, the set screw by which the brush bracket ɔr holder is fixed in position should be slackened and the latter suitably turned or adjusted, the proper position being that in which there is the least possible amount of sparking.

The operation of the dynamo is briefly as follows:—The armature rotating between the poles of the field magnets, a current of electricity becomes excited in the coils of the armature, by reason of the slight amount of residual magnetism of the iron, which current increases the magnetism of the poles, the latter again exciting an increased current, and the full power of the machine being attained after it has made a few revolutions, the power required to drive likewise increasing in a corresponding ratio, it being, in fact, this mechanical power that is converted into electrical energy.

In dynamos wound on the series principle, which are more especially intended for supplying the current to a considerable number of arc lamps arranged in series, that is to say, in such a manner that the current will pass through the whole of the lamps one after the other, the entire current is allowed to pass through the field magnets. On the other hand, in the case of dynamos wound on the shunt principle, which are especially adapted for the purpose of charging accumulators, and also with certain modifications for arc and incandescent lighting, only a portion of the current is permitted to pass through the field magnets. Whilst in a third form of dynamo machines wound on the compound principle, which are adapted for the supply of electricity to both arc lamps and incandescent lamps at the

same time, the field magnets are so arranged that the entire current will pass through a part of them, and a portion only of the current through the remainder of them, the one part being series wound with thick wire, and the other part being shunt wound with fine wire.

This latter type of dynamo would be the most suitable for use at a tea factory, as it can be employed either for lighting by arc or by incandescent lamps, or for both together, the latter being a specially advantageous feature for the purpose under consideration, where arc lamps can be advantageously employed for lighting the yards and spaces outside the factory, and incandescent lamps for performing a similar office within doors.

An important point in connection with the dynamos employed for generating the necessary current of electricity is the provision of proper foundations. Wherever possible the machines should be firmly bolted down to a block of masonry, or, where this is not possible, it should be secured upon a wooden framework so constructed as to be perfectly rigid and unyielding. It is a good plan, where belt-driving is employed, to so mount the dynamo machine upon rails fixed to the foundation that it can be adjusted to and fro thereon by means of set screws, thus admitting of the slackness of the belt being taken up when necessary.

To insure efficiency it is absolutely necessary that each dynamo be driven at the fixed uniform speed, arranged as most suitable, which is usually marked on it, and, consequently, it will be found preferable to drive by a separate motor fitted with a governor of extreme sensibility, rather than from a line of shafting driving other machinery, unless, which is rarely the case, the speed of the latter be tolerably uniform, and does not vary more than two and a half, or, at most, three per cent. Direct coupling to a separate engine would of course be preferable to belt driving. A compound-wound dynamo machine will maintain a constant electro-motive force in volts, without being affected by any variation in the numbers of ampères of current that may be required of it, owing to variations in the external circuit caused by the turning on or off of one or more of the lamps, provided, however, that the speed of driving be maintained practically regular. As this latter is not to be depended upon, it is usual to provide for any minor variations in speed by employing a series of resistance

ils in the shunt circuit between the terminals of the dynamo, r the modification of which resistance the amount of current sent rough the coils of the dynamo, which are wound in shunt, can e increased or diminished, thus compensating for the irregularities in the speed of driving, and keeping up a fixed electromotive force or difference in potential between the two main erminals of the generator.

It is desirable that the dynamos be fenced or partitioned off oth to avoid accidents by interference from uninitiated persons, nd also in order that they may be located in such a position s to be as well protected as possible from damp, dust, and the ccess of any metallic particles. It is, moreover, essential that hey be constantly maintained in a perfect state of cleanliness, ll accumulations of waste oil being regularly removed, as also he metallic dust produced by the constant wearing away of the rushes and commutators.

The conducting wires are of copper, and need only be insulated for inside work, those used for external work being bare and supported by porcelain insulators on poles. The size of the wires necessary will of course depend on the strength of the current in ampères, and will vary throughout any system in proportion to the number of lamps in use, the usual allowance being two ampères for each square millimetre of section of the wire.

In an electric light circuit for lighting by both arc and by incandescent lamps, the positive terminal of the dynamo should be connected to the main switch board, and the negative terminal of the dynamo to a fusible cut-out, to which latter all the return wires of the various circuits should be also connected, and which cut-out, together with any other cut-outs that may be required in the separate circuits, are formed of short lengths of lead wire, each supported between a couple of terminals, the lead wire melting upon the strength of the current passing a certain point previously fixed upon, and thereby breaking the circuit and preserving the latter, and the lamps in it, from being destroyed. A cut-out with a lead wire of suitable diameter should also be located at each principal junction in the incandescent system.

When putting up an installation, the main switch-board and

the fusible cut-out should be arranged upon one of the walls of the dynamo room in such positions as to be readily get-at-able, and care should afterwards be taken during work to see that the contact surfaces of the switches are maintained perfectly free from dirt.

The positive terminal of the dynamo should be connected up to the positive bar of the switch-board from which it may be branched off to the different circuits, that leading to the incandescent lamps being first passed through a fusible cut-out, and then to a switch, by means of which it can be turned on and off as desired, another switch being provided to each group of lamps, or preferably to each individal lamp.

A separate circuit will be required to every two arc lamps working in series with an electro-motive force of 120 volts, or for one arc lamp working in derivation with an electro-motive force of 70 volts, and each of such circuits will have to be passed through a regulating resistance coil, a fusible cut-out, and a switch for making or breaking the electric circuit, and an ampèremeter should also be provided through which the current to the lamps or lamp can be passed, and the strength of the current regulated until the pointer or index hand of the ampèremeter indicates the number desired, that at which it is considered advisable that each arc lamp should be worked being generally marked on the latter. This test should be occasionally repeated as some variation may have occurred in the interim.

When first starting a dynamo it is necessary to exercise great care; the brushes should be lifted off the commutator, and it should be permitted to run free for some time at the proper speed, care being taken to see that it is well oiled. The driving belt must be properly adjusted, and, if a separate engine is provided for driving, the governor should be set to the proper speed.

When these items have been seen to, the brushes should be so adjusted that they will come in contact with the commutator at opposite points of the same diameter, care being taken to ascertain that their holders do not come in the way of the revolving armature, and that they are securely fixed in their proper position. The oil cups should be full of suitable oil,* and no

* The lubricant recommended for use with a dynamo is mineral oil having a density of about ·905.

onnection should exist between any part traversed by the urrent and the framework of the machine. The brushes being hen raised, and all the principal switches opened so as to prevent he passage of any current, the engine can be started, and after . few revolutions the brushes may be lowered down until they ome in contact with the commutator, when, if no undue heating ccurs, and the required number of volts for the installation e indicated upon the voltmeter, the incandescent lamps may first e gradually turned on, and subsequently the arc lamps one by one.

Every additional call made on the dynamo will most probably render it necessary to effect a further adjustment of the brushes, by rotating their holder until there is no sparking.

Should it happen when in operation that the proper number of volts cannot be obtained by the alteration of the resistance, the speed of the dynamo should be increased until such time as the required number is indicated by the voltmeter, bearing in mind that an excess of more than five volts above this latter will result in the rapid destruction of the incandescent lamps.

To insure good results the contact surfaces of the brushes and of the commutator must be maintained perfectly clean, and it is necessary, owing to the powerful attraction generated, not to bring any tools or other iron articles near the dynamo whilst it is running.

To check or arrest the operation of the dynamo, having first opened the switches, next stop the engine, taking care to lift the brushes off the commutator before the rotation of the armature has entirely ceased.

There are numerous varieties of arc lamps, but a detailed description of them would both take up too much space to be gone into here, and is, besides, beyond the scope of this work.

The arc lamps should be so hung that they can be easily lowered for cleaning and other purposes. The mechanisms of the lamps are so arranged that the two carbons will be maintained at a certain distance apart, the voltaic arc which gives the light being formed across this space or clearance, and the resistance produced being got over by the electro-motive force of the current.

The upper carbon, whose holder is connected to the positive pole of the dynamo, will be consumed twice as quickly as the lower one, and is consequently made of double the thickness

of the lower carbon; and the latter one will have a crater formed at its end when lighting, whilst the former will remain constantly pointed. In mounting the carbons they should be placed point to point and accurately in line.

In choosing the candle-power of the lamps two points have to be considered: the extent of the space that it is required to light, and the nature of the work that is to be done by the artificial light which they produce.

For out-door use arc lamps of 19,000 candle-power may be suspended from poles at a height of 100 feet or more from the ground, a lamp of this power requiring a current of 50 amperes. For lighting the open spaces near tea factories, however, lamps of 5,000 candle-power, requiring a current of 24 ampères, and suspended at an elevation of 40 or 50 feet, would, as a rule, be found sufficient, each of such lamps being capable of illuminating an area of about 1,000 square yards; or where less space is required to be lighted a 1,500 candle-power lamp, requiring a current of 13 ampères, and hung at a height of 30 feet, would be found to be powerful enough, the latter being likewise suitable for indoor use.

Incandescent lamps, as is well known, consist of glass bulbs containing U-shaped or looped thin carbon filaments, the air being exhausted from the bulbs which are attached by their stems to metal, wooden, or other holders, in each of which connection is made between the electrical conductors and the ends of the wires holding the carbon filament of the lamp, the latter wires projecting through the stem of the glass bulb for that purpose.

The life of an incandescent lamp varies considerably, longevity being promoted by regularity of current, whilst variations in the speed of the dynamo, constant stopping and starting, etc., tend to shorten its life. Taking, therefore, everything into consideration, although an incandescent lamp is capable of burning under the most favourable circumstances for 2,000 hours, the average life will not as a rule be found to be much more than 800 hours.

Pumping Machinery.

Pumps will be required on tea plantations for raising water for stock, boiler feeding, drainage, and other purposes. The

following are a few of the types of pumps which would be found most suitable for use on tea plantations.

A very useful type of apparatus for raising water is the pulsometer steam pump, the construction of which is shown in Fig. 194, which view represents a vertical central section through a pump of this type fitted with grid valves. As will be seen from the illustration, the pump consists of a single pear-shaped casting, called the body, in which casting are two chambers A, joined side by side and having tapering necks or passages bent towards each other, and surmounted by another casting called the neck which is accurately fitted and bolted to the main casting, and in which the two passages terminate in a common steam chamber I, wherein a ball or spherical valve is so fitted as to be capable of oscillation between seats formed in the junction, and to which steam can be supplied through a pipe K. At their lower ends the chambers A are each connected through one of the suction valves E with the suction passage or pipe. A discharge chamber, common to both chambers, and leading to the discharge pipe is likewise provided, which discharge chamber is also fitted with two valves F, as shown in dotted lines in the sketch. D is an air chamber

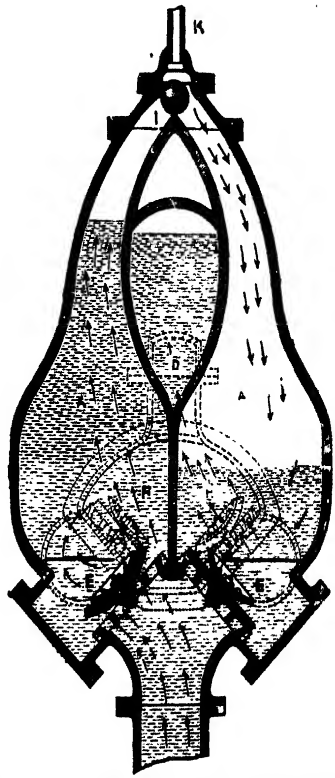

FIG. 194.—Pulsometer Steam Pump with Grid Valves (vertical central section).

which communicates with the suction. Both the suction and discharge chambers, it will be seen, are closed by covers which are accurately fitted to the outlets by planed joints so as to be readily removable when access to the valves is required, hand holes being provided in addition in these covers in the larger sizes of pumps. Guards of the usual pattern are provided for controlling the amount of opening of the valves E, and small air cocks are also screwed into the main or water chambers A, and in the air chamber D.

The operation of the pump is as follows: The chambers A are first filled with water, either by pouring it through a plug hole provided for that purpose, or by drawing the charge. Steam can then be admitted through the steam pipe K by slightly opening a small stop valve, and will pass down that side of the steam neck which is left open to it by the position of the ball or spherical valve I, and the steam pressing upon the small surface of the water in the chamber A which is exposed to it will depress this water without giving rise to any agitation, and consequently with but a very slight amount of condensation of steam, and will drive or force it through the discharge opening and valve into the rising main.

As soon as the level of the water has reached the horizontal orifice which leads to the discharge, the steam will blow through with a certain amount of violence, and through being brought into intimate contact with the water in the pipes leading to the discharge chamber, will become instantly condensed, a partial vacuum being in consequence so rapidly formed, in the chamber from which the water has just been expelled, that the ball or spherical valve I will be drawn over into the seat opposite to that which it had occupied during the emptying of the chamber, closing its upper orifice, and preventing any further admission of steam, and thereby allowing the vacuum to be completed, upon which water will immediately rush in through the suction pipe, lifting the inlet valve E, and will rapidly re-fill the chamber A. The like action then takes place in the second chamber A, and so on continuously so long as the pump is at work, the change being so rapid that, even when no air vessel is fitted to the delivery, but little interruption in the flow of water will be noticeable, the stream being under favourable conditions almost continuous.

The use of the air cocks in the water and air chambers A and D is to prevent the too rapid filling of the chambers on low lifts, and for other purposes, a very little practice enabling an unskilled workman, or even a boy, to set them by means of the small nut with which they are fitted, so that the best effect may be obtained.

The action of the ball, or spherical valve, in the steam chamber I is very certain, and no matter how long the pump has been standing, it will start as soon as dry steam is admitted. The ball, or spherical type of distributing valve, indeed, if once made true, will wear itself and its seats true, as it turns on itself at every stroke, so that no part of its surface will fall twice in succession upon the seat; and, consequently, it is found to be the best form yet designed for the purpose.

The pattern of pump shown in Fig. 194 is fitted, as has been already mentioned, with grid valves, which type of valves are those most commonly employed, having proved to be the most convenient for general work, both by reason of simplicity of construction and durability, and also on account of the great facility with which repairs can be executed, it being but a matter of a few minutes for an unskilled workman to remove the nut and guard, and to put on a fresh rubber washer or disc. The grids employed, when the pump is used for raising water, are of brass, as also the spindle and nut, and they are bolted down by bolts properly pitched round the circumference.

In some instances, however, either clack or ball valves are provided, the former being usually used in the larger patterns of pumps, and the latter in the smaller ones. The clack valves may be constructed of iron with wood seats, in which case hickory is found to be the most suitable wood for the purpose, or rubber-faced clacks may be employed. The ball or spherical valves are made entirely of iron with iron seats, gun-metal with phosphor bronze seats, or rubber balls with gun-metal or iron seats.

Any of the above-mentioned types of valves are supplied for foot and back pressure valves, that which is most usually employed, however, being a 3-lip patent valve, which will close round any foreign object, and has been found to give excellent results.

A drawback to the use of this class of pump has hitherto been

the increased steam consumption as compared with that of direct acting pumps, but this objection has now been to a great extent removed by an arrangement termed a "grel," by means of which the well-known principle of steam expansion has been rendered applicable, and a saving of from 25 to 50 per cent. of the total steam consumption has been rendered possible. The device consists essentially of a box or casing placed above the neck, and containing a secondary cut-off valve, the use of which, in addition to the usual distributing valve, enables a long interval to intervene between each pulsation, during which no steam is allowed to pass through the steam pipe, although the work of pumping is going on continuously.

The pulsometer steam-pump is adapted for pumping water to a total height of from 70 feet to 80 feet, or even to a much greater height under special conditions. The length of vertical suction varies with the different sizes of pumps, being from 6 feet to 10 feet for the smaller, from 8 feet to 12 feet for the medium, and from 10 feet to 15 feet for the larger sizes. If necessary, however, pulsometers can be supplied for 20 feet vertical suction. The length of horizontal suction and discharge is not very material, provided, of course, that sufficient size of pipe be used to prevent excessive friction.

The steam pressure required at the pump for lifts of from 20 feet to 40 feet would be from 20 lbs. to 30 lbs. per square inch, and for lifts of from 40 to 80 feet from 30 lbs. to 50 lbs.; higher lifts require greater steam pressure.

An advantage possessed by this type of pump is that it will work satisfactorily when suspended from a chain or rope, and so can be readily drawn up should a sudden influx of water take place; and, consequently, it is to be especially recommended for use in awkward positions, and for trying work.

A useful application of the pulsometer pump is for raising water for stock, and for boiler feeding and other purposes. A pattern of pump suited for this class of work is one mounted on high, light, wrought-iron travelling wheels, and is used in conjunction with a portable boiler, also mounted on wheels; or, if desired, the pump and boiler may both be mounted on the same wheels, as shown in Fig. 195. The pump is so connected with the carriage as to be readily detachable, and is complete with foot-valve and

elbow, and a suitable length of flexible steam hose, wheel-valve, and discharge air vessel. This apparatus could be advantageously utilized in case of need for fire-extinguishing purposes.

A type of pump which would be of great service on tea plantations for drainage, and also, should occasion arise, for use for fire-extinguishing purposes in the factory, is the duplex—that is to say, a form of machine wherein two steam pumps are placed side by side, and combined in such a manner as to reciprocally

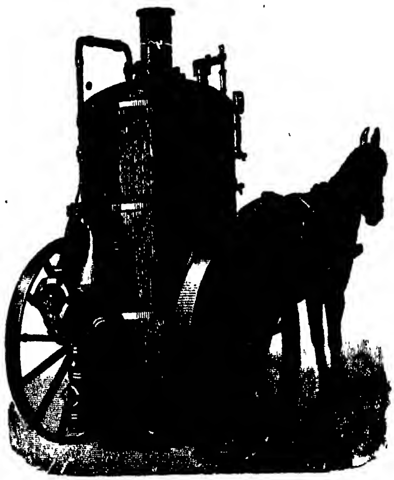

FIG. 195.—Pulsometer Pump and Boiler Combined, Portable Type.

operate the steam valves of each other, the one piston acting to give steam to the other, and subsequently terminating its own stroke, and waiting for its valve to be acted upon before it can renew its own movement, which momentary pause is found in practice to admit of all the water valves seating themselves quietly, and to obviate all harshness of motion. Another advantage possessed by this description of pump is that as the one or the other of the steam valves must be always open, no dead point can exist, and the pump is therefore always ready to start as soon as the steam is admitted, and can be managed by the simple shutting and opening of the throttle valve.

No better example of pumps of the duplex pattern can be given than the Worthington duplex steam pump, which has deservedly gained a world-wide reputation, and Fig. 196 shows a sectional view of one side or half of one of these pumps of the high pressure standard, or regular pattern.

The valve which is shown at E is, it will be seen, an ordinary slide-valve working upon a flat face over ports or openings, and the simplicity and durability of this type, as compared with other steam valves, is too well known to need any comment. In fact,

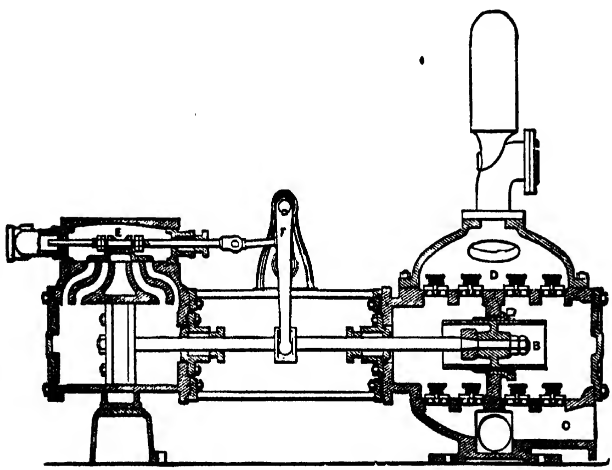

FIG. 196.—Duplex Steam Pump, High Pressure Pattern (vertical section)

this form of valve possesses several admirable qualities, for instance, no matter how long the engine may stand idle, it will not rust or adhere to its seat, and will be always ready to start when required; no collection of water can be formed in its cavities to give rise to trouble; and, without any doubt, it is by far the simplest and most reliable contrivance for the purpose at present known. These and other qualities have enabled it to retain its place on locomotives and other forms of high pressure crank engines in spite of the numerous attempts which have been made to supersede it.

The motion of the valve E is produced by a vibrating arm F, which swings through the entire length of the stroke, with a long and easy leverage, and as in this case the moving parts are always in contact, the blow inseparable from the tappet system is avoided; in fact, this motion is claimed to be superior as regards moderate friction and durability even to the well-known eccentric upon crank engines.

The double acting plunger B works through a deep metallic packing-ring bored to an accurate fit, being neither elastic nor adjustable. This arrangement admits of both the ring and plunger being quickly removed so that they can be either refitted or exchanged for new ones, and also if it should be found desirable at any time to change the proportions between the steam pistons and pumps, a plunger of somewhat larger size, or one of smaller diameter, can be readily substituted, and as the existence of exact proportions between the power expended and work done are always desirable, if not absolutely necessary, this latter will be seen to be a feature of considerable importance. Practical experience, moreover, has proved this system of renewal of working parts to be both the cheapest and the most satisfactory one for ordinary work.

The plunger B is, it will be seen, located some inches above the suction valves, thus forming a subsiding chamber, into which any foreign substances may fall and where they will rest below the wearing surfaces. This arrangement tends to prolong the life of the parts far beyond that usual in the ordinary form of piston pump, more especially when pumping water containing grit or other solid material.

In operation the water enters the pump from the suction chamber C through the suction valves shown in the illustration, thence passing partly around, and partly by the end of the plunger through the force valves, nearly in a straight course into the delivery chamber D, thus it will be seen traversing a very direct, and at the same time ample, water-way.

The valves consist of several small discs of indiarubber or other suitable material, and are easy to examine, and inexpensive to replace when worn out; their location, moreover, on the top and bottom plates furnishing a large area for their accommodation.

As all the parts of the valve motion are constructed of steel,

the circular parts being made from rolled steel rods, and other irregular parts being drop forged, and as the wearing surfaces are amply large, and all the pins hardened, it will be seen that this pattern of pump must be very durable.

The proper disposition of the pipe connections being a matter of considerable importance, the illustration (Fig. 197), which shows a good arrangement for the purpose, will be of service to those requiring to put down a pump of this description, and, not being fully acquainted with the best method of doing so.

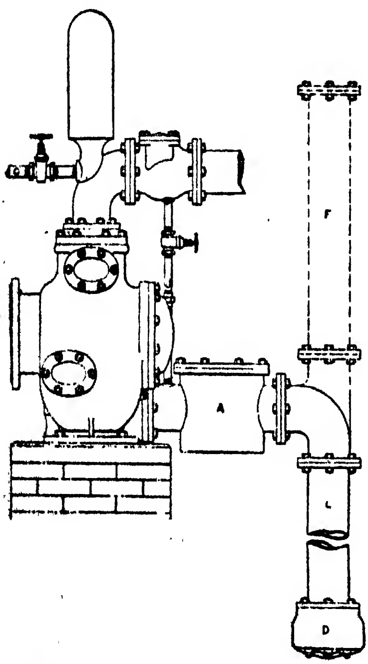

FIG. 197.—Method of Arranging Pipe Connections of a Duplex Steam Pump.

In this view C is the suction pipe which is fitted with a foot-valve D, which serves to keep the pipes and cylinders charged with water, so that the pump when being started does not have to free itself and the suction pipe of air. The provision of this valve is always essential on an unusually long suction pipe, or where there is a severe suction lift. In such cases it will also be found advantageous to add a vacuum chamber, and this can be readily done by extending the suction pipe in an upward direction, as shown in dotted lines at F.

A is a strainer-box, which is fitted with a large basket strainer, so arranged as to be easily withdrawable for cleaning purposes.

...ck valve should be placed upon the delivery pipe to keep ...he water when the pump is opened for examination or repairs. ...waste delivery or starting pipe, that can be led into any

onvenient place of overflow, should be provided, so that the ump at starting can be allowed to free itself of air, while the ressure is kept from it by the check valve. When the pump as properly started the valve in the waste delivery should e closed.

J is a pipe which connects the delivery pipe beyond the heck valve with the suction chamber of the pump, for the purpose, before starting the pump, of charging the cylinders and suction pipe with water from the delivery pipe, should they have been purposely emptied, or the water have leaked out through the foot valve. B is the flange at the suction, or supply opening, of the pump.

Should any difficulty be experienced in getting a pump of this type to work properly when first started, as a general rule, it will be found to proceed from imperfect connections, or from the temporary stiffness of all new machines. It sometimes happens that a pump will refuse to lift water while the full pressure, against which it is expected to work, is resting upon the force valves, for the reason that the air within the pump chamber has not been dislodged, but has been only compressed by the motion of the plunger. The pump should, therefore, be run without pressure until all the air has been expelled and water follows, and this can be effected by placing a check valve in the delivery pipe and providing a waste delivery, to be closed after the pump has caught water; this valve is also used for keeping back the pressure when the pump is opened to make an examination of the valves.

The steam valves of a Worthington duplex steam pump are set in the following manner:—Place one piston in the centre of its stroke and the opposite slide valve in its central position. The piston can be set in the middle or centre of its stroke by opening the drip cocks and moving the piston, by levering over the cross-head, until it comes in contact with the cylinder head, a mark should then be made on the piston-rod at the face of the steam end stuffing-box follower, and the piston be then moved back to contact stroke at the opposite end, and a second mark be made half-way between the first mark and the above-mentioned follower. By now moving the piston until the second mark coincides with the face of the same follower, it will be exactly in the centre of

its stroke. It is desirable to place both pistons at the middle of their strokes before touching either of the slide-valves. The lock nuts should be so adjusted, as to allow about three-sixteenths of an inch lost motion on each side of the jaw, and the valve set, and the valve motion should not be disconnected. To divide the lost motion equally, move the valve each way until it strikes the nuts and see if the port openings are equal. Too much lost motion will tend to lengthen the stroke, and endanger the cylinder head, whilst, on the other hand, should the lost motion be not sufficient the stroke will be perceptibly shortened.

Both valves are, of course, set in the same manner.

Where a large quantity of water has to be raised to a moderate height the best type of pump to employ is the centrifugal, inasmuch as a pump of this kind is capable of discharging a greater volume of water for the consumption of power than any other. Further qualities which they possess are: great simplicity and strength of construction; facility of erection and repair; adaptability for use in cramped positions; and, finally, a capacity for lifting water in which considerable quantities of mechanical impurities are held in suspension, such as sand, gravel, vegetable matter, and other materials, by which the ordinary forms of pumps would be quickly choked and rendered inoperative. As will be seen from the above, these pumps possess qualities which render them especially suitable for drainage purposes.

All pumps of this class comprise a set of suitably curved blades, rotatably mounted in a casing, and the revolution of these blades produces a certain amount of vacuum, which results in the water rising into the casing. The limit of lift possible is about 25 feet, but it should not, as a rule, be used for more than 20 feet, up to which height it acts well, although not discharging so much water as at lower lifts, and half the above, or 10 feet, being about the most advantageous.

It is advisable to obtain centrifugal pumps from some one of the makers of repute, as a badly-designed pump of this type gives rise to a very considerable amount of loss through friction, owing to the want of evenness in the flow of water through it.

It is desirable that a centrifugal pump should be fitted with an exhauster, which can be worked from the pump spindle, as by

this means the air in the pump and pipes can be exhausted, and the necessity of filling up with water at starting is avoided.

In the best forms of centrifugal pumps the blades are made of steel as well as the spindle, and all the working parts should be very carefully balanced.

The speed at which a centrifugal pump is run must be in proper proportion to the height to which the water is to be raised, and, to a certain extent, by increasing the speed either the amount of water discharged by the pump can be increased, or else the water can be raised to a greater elevation.

Centrifugal pumps may be driven by belt gearing from any suitable source of power, or they mao be driven direct by special steam engines, or by horse, or other animal power, or by a wind motor or engine.

In Fig. 198 is illustrated a double-acting centrifugal pump, with all the latest improvements, constructed by Gwynne & Co., London.

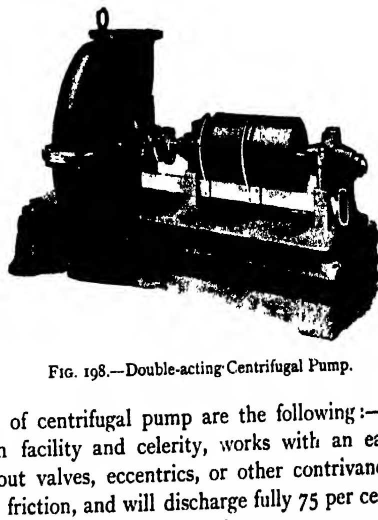

FIG. 198.—Double-acting Centrifugal Pump.

Amongst the advantages claimed for this patent type of centrifugal pump are the following:—It can be erected with facility and celerity, works with an easy rotary motion without valves, eccentrics, or other contrivances consuming power in friction, and will discharge fully 75 per cent. on the average more water in proportion to the power consumed than any other pump.

These pumps are made in various sizes adapted to raise from ninety gallons to seven thousand gallons per minute.

A device for raising water, which would be found very useful on many tea plantations, is the hydraulic or water ram, or *belier hydraulique*, which device, invented in a crude non-automatic form by Whitehurst in the year 1772, was improved and rendered

automatic in its action, by the simple addition of a water valve, by Montgolfier in 1796—1802, and was subsequently further improved by his son. The principle remains the same up to the present day, but certain modern improvements in details of construction have rendered the hydraulic ram more economical in its operations and more durable.

The principle upon which this apparatus works is that a larger column or body of water, with a certain fall, will force or raise a smaller column or volume of water to a higher level than that of the driving water supply. This, it will be seen, is simply a practical application of an old and well-known mechanical law of forces, viz., that the useful effect produced by a body is as its weight multiplied by its velocity, the momentum being its actual force.

The improved patterns of hydraulic rams are perfectly automatic in action, and will continue to work with extreme regularity so long as the machine remains undamaged and the water supply lasts. As, however, they are as a general rule left to take charge of themselves, care should be taken to choose only those that are simple in design and strongly constructed, and especially to observe that the beat, delivery, and snifting valves are of the most approved patterns, and of the best material and workmanship.

In fixing an hydraulic or water ram, too high a fall of driving water should, if possible, be avoided, as in such a case the friction engendered by the force of the water would cause a rapid deterioration of the working parts; again, on the other hand, if the available fall be very low the quantity of water that can be raised will be, of course, small.

The proportion of fall required to the lift is about one to ten, and the proportion of water lifted or forced to a higher level to the total supply is about the same; that is to say, one gallon of water will be raised or forced to a given height for every ten gallons of driving water that pass through the ram.

As an approximate rule it may be taken that water can be forced or driven up by a water ram to ten times the height of the head of driving water.

Let it be supposed, by way of example, that a fall of 6 feet can be obtained in the supply or injection pipe, this would maintain

a percussive action on the ram sufficient to force the water in small quantities to a height of 60 feet, whilst double the above, or a fall of 12 feet, would force it to a height of 120 feet, and so on. A rapid decrease in the percentage of efficiency, however, will be experienced, as the height to which the water is to be raised increases above that of the fall.

The following particulars and illustration (Fig. 199) of the hydraulic ram are given by Mr. Kempe.* The water working the ram is supplied through the pipe S, and escapes through an opening at *o*, until it has gained a velocity sufficient to raise the valve or ball B, which suddenly stops the current and causes an excessive pressure in the ram R which opens the valve or ball C; the water is forced into the vessel or air-chamber A, and finally through the delivery-pipe *d* to its destination. When equilibrium of pressure is restored between S and R, the ball B falls, and the operation is repeated. The ram can make as many as 200 strokes per minute, depending upon its size.

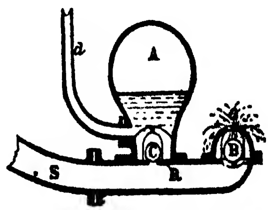

FIG. 199.—Hydraulic Ram (vertical central section).

The length of the supply-pipe S should not be less than five times the height of the fall. But the delivery-pipe *d* may be made ten times, or more, the height of the fall.

In ordinary cases the hydraulic ram returns about 50 per cent. of the natural effect. That is, the quantity of water *q* multiplied by the height *h* of the delivery above the ram will be about 50 per cent. of the quantity of water Q working the ram, multiplied by the head of fall H in the same unit of time.

$$qh = 0{\cdot}5QF. \qquad q = \frac{0{\cdot}5QH}{h}. \qquad Q = \frac{2qh}{H}.$$

Q and *q* can be expressed in any unit of volume or weight. F and *h* can be expressed in any unit of length.

* "The Engineer's Year-Book of Formulæ, Rules, Tables, Data, and Memoranda in Civil, Mechanical, Electrical, Marine, and Mine Engineering," by H. R. Kempe (London: Crosby Lockwood & Son).

If Q and q = cubic feet per minute,
F and h = fall and height in feet,
L = length in feet, and D = diameter in inches, of the supply-pipe S,
l = length, and d = diameter, of the delivery-pipe d.,

$$D=\sqrt[5]{\frac{2Q^2(L+5D)}{F}}, \qquad d=\sqrt[5]{\frac{4q^2(l+5d)}{h}}.$$

Machine Tools.

Fig. 200 is an enlarged plan of the small repair shop J shown in the plan of the complete tea factory. K are the lathes, which may consist advantageously of a 10-inch centre self-acting, sliding, surfacing, and screw-cutting lathe, and a 6-inch centre screw-

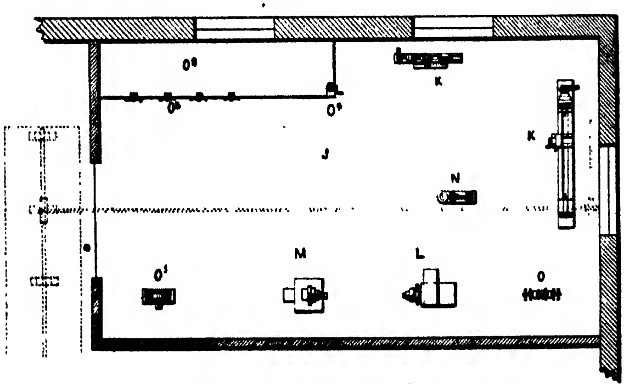

Fig. 200.—Plan of Engineer's Workshop for Tea Factory.

cutting lathe, the latter being arranged to work by either foot or steam power. L is a 6-inch shaping machine, M is a milling machine, N is a 30-inch power drilling machine, O is an emery grinding machine, and O¹ is a grindstone. O² is a fitter's bench provided with vices O³, and a hand-power drilling machine O⁴. The countershafts of the machine tools are driven from an overhead shaft, shown in dotted lines in the drawing, which shaft itself receives motion from the main line of shafting in the pit through a crossed belt.

The larger lathe, which is placed across the shop, may be either

driven through a ground countershaft on to the overhead motion, as shown in dotted lines, or direct from the overhead shaft to the overhead motion by means of a belt carried round an idle pulley.

This larger lathe should have a gap bed 12 feet in length, by 15 inches in breadth, and 10½ inches in depth, the gap being 15 inches in breadth by 10½ inches in depth. The cone should have four speeds, and be suitable for a 3-inch strap, the large cone being 12½ inches in diameter by 3⅛ inches in breadth, and the large wheel 14½ inches in diameter by 3 inches in breadth. The guide screw should be 3⅛ inches in diameter by ½ inch in pitch. The headstocks double-geared, amply powerful, and fitted with steel spindle preferably supported in conical bearings. The carriage should have a self-acting motion imparted to it by a back shaft, a quick hand traverse motion by means of a rack and pinion, a slide-rest made to turn conical, and indexed to set to any angle, and a back following stay. The guide-screw should be accurately cut, and be provided with double clamp nuts, a set of 22 change wheels and reversing motion for cutting right and left hand screws.

The back shaft should be so mounted as to be clear of the gap, and not to require moving when it is desired to surface an object the full size of the gap.

A top or overhead motion will be also required, having a speed cone, fast and loose pulleys, hangers and shafts. A lathe of the above description is capable of admitting between centres work up to 7 feet 6 inches in length.

The small lathe should have a gap-bed 6 feet in length, the bed being 8 inches broad by 5¾ inches deep, and the gap being 6¾ inches deep by 7½ inches wide. The guide screw should be 1⅜ inches in diameter, with four threads to the inch. The change wheels should be $\frac{5}{16}$ inch pitch. The treadle should be fitted with an antifriction motion, and the driving shaft should carry a heavy balance fly-wheel, and a speed cone with four speeds for 1½-inch belt.

As regards the shaping-machine, the bed of a machine of this size should be 2 feet 9 inches long by 2 feet 7 inches high, table 14 inches by 13 inches by 12 inches deep, and capable of taking work 12 inches deep on the top. It should have a variable stroke up to 7 inches, driven by cone, wheel, and pinions. A head traversing along the bed 1 foot 10 inches, and having self-acting surfacing cut with variable feed. The ram should be indexed and fitted with slides for

down cutting and angles. The table should have planed T-slots on both the top and side, and be adjustable on the bed in a horizontal direction, and vertically by a screw with bevel wheels and front operating handle. Self-acting circular motion for external curves should be provided, and a complete top motion.

A parallel vice, for fixing on the table to grip a certain class of work, will also be required.

A useful type of milling machine for use in a repair shop would be Brown and Sharpe's small universal milling machine. This machine has all the movements of a plain milling machine, and, in addition, is fed automatically at an angle to the axis of the spindle, and is provided with an adjustment which enables it to be stopped at any desired point. The knee is capable of being moved perpendicularly through a distance of 14 inches, and has a dial giving a reading in thousandths of inches. The saddle supporting the spiral bed is also provided with a movement of 6 inches parallel to the axis of the main spindle, which movement is also indicated in thousandths of inches.

The spiral bed carries a head and a foot stock having centres upon which reamers, taps, drills, or mills, can be held for grooving, etc., either straight or spiral, right or left hand.

The head holding one centre can be set at any angle between five degrees below a horizontal to a perpendicular or vertical position, and upon a mandril inserted in the spindle can be cut angular mills, cutters, or bevel gears. The head can also be placed at a right angle on the bed, and operations performed upon the face of work held in a chuck, which latter fits on the end of the spindle.

A vice for clamping on the bed at any angle has jaws 5 inches wide by 1 inch deep, and capable of opening 2¾ inches.

Change gears for different spirals, and index plates for various divisions, together with explanatory tables, accompany the machine, and render its manipulation a simple matter.

The main spindle and the spiral head spindle are reamed to the same taper, so that the mandrils or collets can be used on either, and the hole in the spiral head spindle is extended through the same so as to allow of work being held which is too long to be gripped between the centres, the distance between which latter is 14 inches.

The frame of the machine is hollow and is fitted up to serve as a receptacle for all the small parts.

The front spindle bearing is of hardened steel and both bearings have compensation for wear. The cone has four speeds and is adapted to take a 3-inch belt. The countershaft has one tight and two loose pulleys 14 inches in diameter, the width of the three being 16½ inches. The speed of the countershaft should be 110 revolutions per minute.

As regards the power-drilling machine, a 30-inch double-geared pillar-drilling machine, having a 2-inch steel spindle, and a 20-inch diameter circular table arranged to move round on a turned pillar 6 inches in diameter would probably be found the most suitable for the work to be done in the majority of estate repair shops. Such a drilling machine should have a self-acting, variable feed motion, with some efficient form of instantaneously-acting disengaging motion, and be capable of taking in work up to 30 inches diameter on the table, and of admitting an article 32 inches deep from the top of the table, and 44 inches deep from the foundation or base plate, which latter should be truly planed and provided with T-slots for clamping bolts.

This drilling machine would be capable of boring up to 10 inches in depth, and up to 5 inches in diameter. Four speed cones suitable for 2½ inch belts, the larger cone being 11 inches in diameter, should be provided, and the spindle should be preferably supported in a conical bearing.

The emery wheel, grindstone, bench or other hand-power drilling machine, bench vices, stocks and dies, and other loose tools, are too well known to need any special description here.

Motive Power for Tea Factories.

Motive power for tea factories includes steam and oil engines, turbines and other water motors, electric motors, and wind mills. The latter, however, being of too uncertain a nature to use for main driving purposes, and only fit for working pumps for raising water for drainage or irrigation, or to storage ponds, or tanks, for boiler feeding and other requirements, etc.

Steam Engines.

As regards the steam engine or motor, so much depends upon the size of the factory, high cost or otherwise of fuel, and upon

many other considerations, that it would be impossible to lay down any hard and fast rule as to the best type to employ.

Where economy is a desideratum a compound engine fitted with some efficient form of automatic-governor expansion gear would be found to be the most desirable type of engine to employ. It is advisable, moreover, that the engine be fitted with a properly

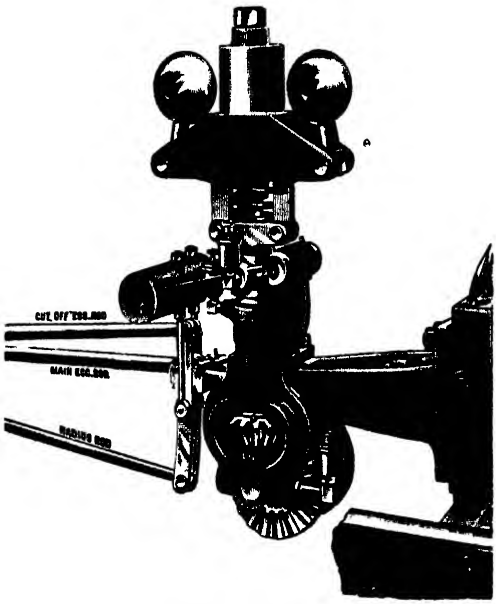

FIG. 201.—Automatic Governor Expansion Gear.

designed jet condenser, which may be placed behind the cylinders, and worked by an extension of the piston rod from the low-pressure cylinder, and, if condenser disconnecting valves be provided, the engine can then be worked at any time either as a condensing or as a non-condensing engine.

A separate surface heater, of either a vertical or horizontal pattern, should be also provided, by means of which the feed water may be raised to a high temperature, and thus a further economy of fuel be effected, and the water besides purified. This

latter apparatus would be of still greater value in localities where the feed water which has to be used is impregnated with lime or other foreign matter.

A patent automatic governor expansion gear made by Ransome, Sims, and Jefferies, Ltd., Ipswich, shown in Fig. 201, is one which, whilst being simple in construction, is also very effective in operation. It consists essentially of an independent gridiron expansion valve, working upon the back of the main slide valve, and operated through a knuckle joint by a link, one end of which is actuated by the cut-off eccentric, whilst the other end is held by a radius rod. The travel of the valve, and the point at which it cuts off, are governed by the position of the link in relation to the knuckle joint, and this position will be varied, in accordance with the load on the engine, by a powerful and sensitive type of governor to which the link is connected.

The above described arrangement provides for varying the cut-off between 0 and 70 per cent. of the stroke, in proportion to the actual load on the engine, the exact amount of steam necessary to do the required work being admitted at full boiler pressure up to the point of the cut-off, thereby insuring the entire benefit of the principle of expansion. The value of a wide range in the cut-off is very considerable, a point which will be very readily seen when it is noted that if the cut-off be effected at 70 per cent. of the stroke, the horse-power given off by the engine will be equivalent to about four times its nominal horse-power.

In addition to the advantage arising from the economy obtained in the consumption of fuel by the adoption of this gear, it is claimed that it insures the speed of the engine being maintained practically constant under the greatest possible differences of load, the variation in the number of revolutions in no case exceeding about 2 per cent.

Fig. 202 illustrates a compound stationary engine by the same makers fitted with the above-described automatic governor expansion gear.

This pattern of engine is, as will be seen from the illustration, extremely compact, and the cylinders and working parts are mounted on a strong wrought-iron girder frame, an arrangement which is extremely advantageous in the case under consideration,

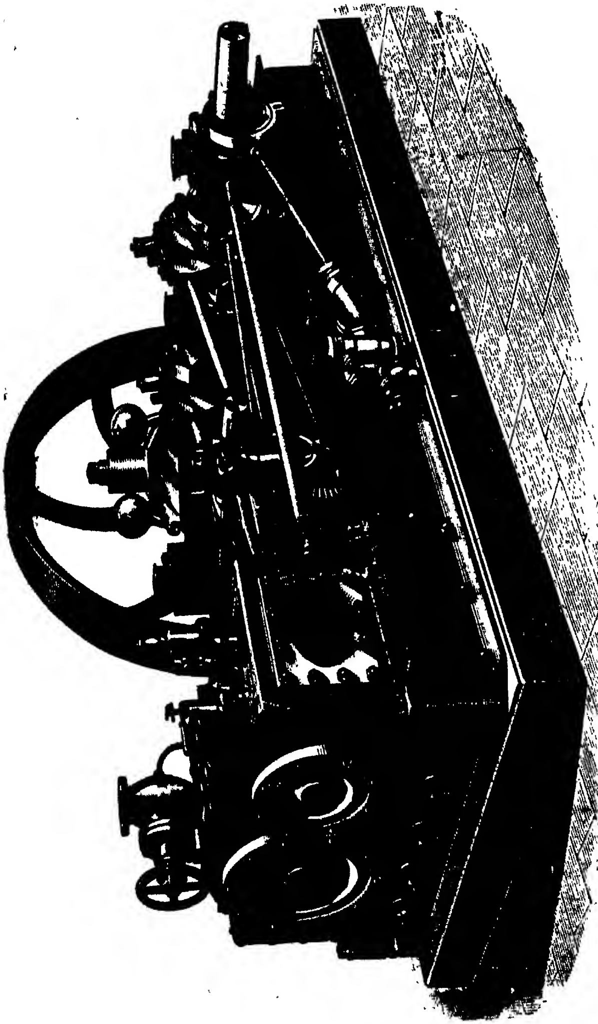

Fig. 202.—Compound Stationary Engine, fitted with Automatic Governor Expansion Gear.

inasmuch as by taking this girder frame to pieces the weight of the packages to be transported can be considerably reduced and transport facilitated. The wrought-iron frame besides is less liable to be broken in transit. The engine is provided with all recent improvements. A sight-feed lubricator is fitted to the steam chest of the high-pressure cylinder, and the jacket is drained by an efficient steam tap. The above described type of engine is built in various sizes from 8 up to 50 h.-p.

Space will not admit of going more fully into the subject of steam engines, but before concluding it may be well to impress upon an intending purchaser that whatever type of engine he may decide upon, he should be careful to see that it is not only compact in design but that it has an extended bed-plate passing entirely beneath the cylinders, and, preferably, also round the outside of the crank sweep, and is generally so constructed as to insure the utmost possible steadiness in running, and ease of starting.

Above all things avoid any pattern of engine having an overhanging cylinder, a design which, bad even in the case of a small engine, is totally inadmissible in that of those of larger dimensions. As regards the details of construction of the engine it is necessary to be assured that it be made throughout of the best materials, and that no pains have been spared to put in the best possible workmanship, the latter being of course greatly facilitated, and accuracy of parts guaranteed, by the ample plant of the newest and most approved tools now at command in all large shops. The cylinders should be made of the hardest close-grained cast-iron, and efficiently steam jacketed, lagged with wood, and covered with planished sheet steel. The wearing surfaces should all be of large proportions, thereby reducing wear and tear to a minimum, and they should also be made easily adjustable. The flywheel should be of ample diameter and width, and turned on the face to receive a belt, and steel should be employed for all piston and valve rods, and crank pins, and the working gear be case hardened throughout.

Steam Boilers or Generators.

The boiler or boilers required for the generation of the necessary supply of steam for the main and auxiliary engines,

will form an important part of the plant of the factory. In the opinion of the author, the most convenient and best boiler for this service is one of the multitubular or locomotive type, inasmuch as this class of boiler can be transported with great facility, is less expensive and difficult to set, takes up less room, and yet affords an equal heating surface to a Cornish or Lancashire boiler of far larger dimensions, enables steam to be raised quickly and maintained at a high pressure, and finally, but not least, is comparatively easy to repair.

A convenient size for a multitubular boiler for the purpose under consideration is 7 feet in diameter by 12 feet in length, and fitted with 142 tubes. Such a boiler should have a shell of Martins-Siemens steel plates, $\frac{5}{8}$-inch thick, and double riveted in the longitudinal seams. The end plates should be each formed in one piece, $\frac{7}{8}$-inch thick, of the same material, and should be flanged and riveted to the shell, and stayed longitudinally by means of wrought-iron stays. The tubes should be $3\frac{1}{2}$ inches external diameter, best lap-welded light tubes, and sent loose to put in at factory. The man-hole and mud-hole should be strengthened by wrought-iron rings, and fitted with McNeil covers, or ones of an equally efficient pattern. The horizontal steam chest should be 2 feet 6 inches in diameter by 12 feet in length, and made of steel plates $\frac{7}{16}$-inch in thickness, and on shell ends $\frac{5}{8}$-inch in thickness, being attached to the boiler shell by connections of thick-edged Lowmoor, or equivalent brand, of iron for bolting to wrought-iron faced blocks riveted to the shell.

The fittings for such a boiler as the above should comprise two safety valves with gun-metal seats and having levers and weights, complete for attachment to steam chest. One $2\frac{1}{2}$-inch feed stop and retaining valve with a copper dip pipe. One $2\frac{1}{2}$-inch gun-metal double-flanged and packed gland blow-off cock. One steam-pressure gauge with syphon. Water gauge and gauge cocks, mounted on a cast-iron pillar, connected to a cast-iron curved bracket on the boiler shell, by two wrought-iron pipes with flanges and bolts.

The fittings for the furnace should consist of one furnace and ash-pit frame with air-tight doors provided with protection plates. A set of 55 fire bars, 2 feet 6 inches by 4 inches by 2 inches, weighing 1 qr. 2 lbs. each, bearers, fire plates, and cast-iron grating plates.

Smoke box frame of cast-iron, doors, and protection plates. Two dampers, one double brick and the other plate with frames and counterpoises.

This boiler should be tested to 120 lbs. to the square inch under cold water pressure, and the working pressure is 70 lbs. per square inch.

The setting of a boiler of this pattern is a matter of comparative simplicity, the shell of the boiler being usually supported upon fire-brick seating blocks. When a battery of such boilers, however, is used, a better plan is to hang or suspend them by means of iron straps from metal girders. This arrangement admits of a more thorough and easier inspection of the outer shell of each of the boilers being made when required, and obviates the danger of unnoticed external corrosion taking place to a dangerous extent, as is frequently the case where the plates rest on the seating blocks.

Oil Engines.

Oil engines could be advantageously employed in tea factories for auxiliary driving purposes, and their use would be of considerable advantage, inasmuch as some of the drying machines, and also a portion of the withering fans, the dynamos, and other machines might be arranged to be driven by such auxiliary oil engines, thus obviating the loss entailed by having to keep the large or main engine going whenever it may be required, as is frequently the case, to run some of the machines after the bulk of the others are no longer required.

There are many efficient oil engines in the market at the present time. For the purpose in question, however, the Hornsby-Akroyd or the Priestman oil engine would be found to be the most suitable. The latter engine, of which a brief description will be given, is made of all convenient powers up to 25 h.-p., and its general appearance and arrangement are shown in the illustration, Fig. 203.

In the rear end of the working cylinder is provided the clearance space into which the air and vapour will be compressed previous to the explosion. The oil reservoir or supply tank is located on the bed of the engine at the opposite side from the fly wheel, and the oil is delivered from this reservoir to the

carburetor or vaporising chamber, and to the heating lamps, by maintaining a pressure of air in the former, the initial pressure being secured by means of the hand pump, shown on the right-hand side of the illustration, and afterwards maintained during the working of the engine by means of an air pump driven by an eccentric, a safety valve being also provided for keeping the air pressure constant, as indicated by a gauge on the tank, and a glass gauge showing the level of the oil in the latter. The vaporising chamber is situated below the working cylinder, and is provided with a jacket through which the hot gases pass.

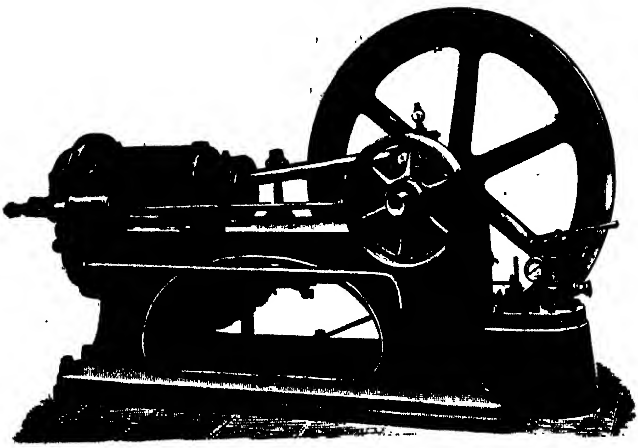

FIG. 203.—Oil or Internal Combustion Engine.

The heating lamps which are placed beneath the vaporising chamber and are only employed for the initial heating of the vaporiser, receive their supply of oil and air, as above mentioned, from the oil reservoir. A six-way cock or valve is so arranged in connection with these lamps that, when the handle is placed upright, the cock or valve will be closed; when turned to the left air and oil will be supplied to the starting or initial heating lamps; whilst when the lever is adjusted to the right, the oil and air supply will be delivered to the spraying device of the vaporiser.

A circulation of water for cooling purposes is maintained through the water jacket of the cylinder by means of a pump on

the engine, or in some cases such circulation may be effected by gravitation from a tank.

An automatic valve and likewise a valve opened by an eccentric on a shaft rotating at half the speed of the crank shaft are provided at the back of the cylinder, the first opening at the suction stroke and admitting the mixed air and vapour from the vaporiser, and the second being opened during the exhaust stroke and allowing the waste or spent gases to pass into the jacket of the vaporiser.

The charge of compressed gas or vaporised oil and air is fired by an electric ignition device, comprising a bichromate battery and an induction coil, the circuit being completed at the desired instant by a contact piece on the eccentric rod passing between a pair of springs. This type of battery has been found to be both efficient and cheap: it will work for from thirty to forty hours for an outlay of 4d. for chemicals—viz., sulphuric acid, 6 ozs.; bichromate of potash, 8 ozs.; and zinc plates nominal—which is at the rate of 1d. per day.

The cost of running an oil engine will, of course, vary in accordance with the price of oil; but when employing a refined petroleum of a similar quality to that used in ordinary lamps for lighting purposes, and at the price prevailing in this country, it would be about 2d. per h. p. per hour.

Those who desire to go fully into the study of oil engines should obtain the very excellent work upon the subject written by Dugald Clerk,* C.E., M.I.C.E., a book which treats most exhaustively of internal combustion or explosion engines, and which has very rapidly gone through a number of editions.

Water Motors.

In some localities fuel is scarce, whilst water power is to be found in abundance, and wherever this is the case, it would, of course, be found most economical to employ the last mentioned as a driving medium; and the most advantageous method of utilizing the power would undoubtedly be by means of some form of turbine or water motor.

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* "The Gas and Oil Engine," by Dugald Clerk, M.Inst.C.E., M.I.M.E., &c. (London: Longmans, Green & Co.).

Certain localities are provided with ample water power, but so situated as to render its direct utilization difficult or impossible. In this case the best plan to adopt would be to use the turbine to drive an electrical generating plant, which could be conveyed to the electric motor or motors at the works. Where the position of the turbine is not too far from the factory rope transmission might be employed. An instance of this description, mentioned by Mr. Christison,* is that of the Tukvar Company, Darjeeling, where the turbine is situated in a ravine about two-thirds of a mile from, and 1,500 feet below the level of, the factory, the power being transmitted to the machinery there by means of wire rope, travelling upon pulleys supported upon standards placed at suitable distances apart.

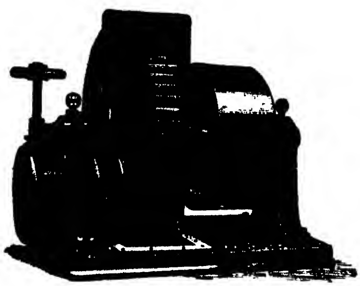

FIG. 204.—High Fall Horizontal Shaft Impulse Turbine.

From the numerous patterns of turbines made, it would not be difficult to make a selection which would be in every way suitable for the work required to be performed in a tea factory; but in all probability none would be found more, if indeed as, suitable as the Girard and Jonval turbines, illustrated in Figs. 204 and 205, which are made by W. Günther & Sons, Oldham.

The view Fig. 204 shows a Girard or action turbine of the horizontal shaft pattern, with a portion of the casing removed to allow the arrangement of the wheel to be seen. In this type of turbine, which is adapted for falls up to 500 feet, the water issues from the guide ports with the full velocity due to the head of water under which it is working, and glides along the concave surfaces of the wheel buckets without touching the convex surfaces. By this it will be seen that it works entirely by impulse, instead of, as in ordinary or pressure turbines, in which the water entirely fills the wheel buckets, partly by pressure and partly by impulse.

* "Tea Planting in Darjeeling," *Journal of the Society of Arts*, June 12, 1896.

This feature renders the Girard turbine suitable for use with a much wider range of falls, and, besides, allows of its retaining its efficiency when working with a reduced water supply.

To admit of the maximum power being obtained, it is necessary to insure the water leaving the wheel at its lowest possible velocity, and it is also requisite to prevent the buckets from becoming filled with water, and this is effected by widening out the sides of the wheel towards the bottom, and thus obtaining small exit angles.

Ventilating holes formed in the sides of the wheel admit air and prevent the formation of eddies in the empty spaces at the rear of the vanes, the water jets being thus caused to pass along the wheel vanes in perfectly unbroken streams.

In fixing a Girard turbine it must be so placed, in the case of high falls, that the bottom of the wheel when working will be just clear of the tail water, so as to secure a perfectly free discharge for the water. This clearance need not exceed a couple of inches, the trifling loss of fall being more than compensated for by the increased efficiency gained.

In the case of low, and sometimes with medium, falls, where the tail water frequently rises above its usual level, and where, consequently, the placing of the wheel at such an altitude as to be at all times above water would cause an appreciable loss of fall, it would be found preferable to employ a special type in which the water jets entirely fill the wheel buckets, and which are capable of working submerged in the tail water without loss of efficiency.

The Girard turbine operating entirely by impulse, each jet acts independently of the others, so that any number of the guide ports may be closed, in order to suit a decreased water supply, without impairing the efficiency of the motor, the water consumed, and the power developed, being thus practically in exact proportion to the number of ports open.

A slide arrangement admits of the guide ports being opened or closed in succession, so as to effect the requisite regulation for variable water supply or power. This plan of adjustment insures no alteration being made in the angle at which the water enters the wheel, and the ports not shut off by the slide are fully charged, so as to thus always work under the best conditions.

For low or medium falls not exceeding 30 feet, and where the water supply is not liable to any considerable variation, the parallel flow horizontal shaft Jonval turbine, shown in Fig. 205, may be advantageously employed.

This turbine, which acts on the pressure principle, is both a simple and efficient example of the type. The water enters the guide ports and leaves the wheel in a direction parallel to its axis, and its course being as straight as possible, the highest efficiency is obtained.

An important advantage possessed by this turbine, especially in the case of large wheels on low falls, is the small depth of standing

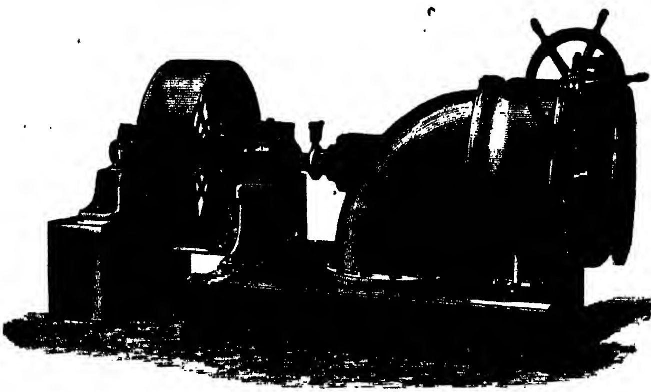

Fig. 205.—Parallel Flow Horizontal Shaft Pressure Turbine.

tail water that is required below the wheel, as compared with that required for turbines of the inward and mixed flow types, thus reducing the cost of foundations, fixing, &c., to a minimum.

The Jonval turbine does not develop as high an efficiency when working at part gate as the Girard, but will give very good results down to about one half gate. The adjustment is effected by closing the guide ports in succession by means of a slide, or slides, in a manner practically similar to that adopted in the Girard.

As the Jonval turbine works when deeply immersed in the tail water without appreciable loss of efficiency, it is, therefore, especially suitable for use in situations where the river is subject to frequent floods, as it will work so long as any fall is available,

and it may be located at any height not exceeding 25 feet above the tail water level, the connection between the turbine and the water being maintained by air-tight pipes, that portion of the fall below the wheel acting in this case by suction.

For low falls of between 3 feet and 8 feet, the turbine should be fixed in an open tank or flume, the arrangement being practically similar to that of the Girard turbine, only placed somewhat lower with the wheel always submerged in the tail water. Large diameter wheels are generally divided into two or three concentric sets of ports and buckets, one or more of which are fitted with an independent adjustment, admitting of working with one or all the sets open or partially closed—an arrangement very useful on falls subject to frequent back water.

In the case of falls from 8 feet to 15 feet, and sometimes up to as high as 20 feet, the open tank or flume may still be used, the turbine being placed at a convenient point between the levels and that portion of the fall acting by suction. No outer casing is required in this latter arrangement, so that the cost will be considerably reduced.

When the fall exceeds 15 feet, or in situations where the line shaft is placed below or close to the headwater level, an iron casing and pipes will be necessary, the turbine being either located in close proximity to the tail water, or above the latter, so as to be always higher than the flood level, and being fitted with a suction pipe. A throttle valve should be also placed in the suction pipes, or in the pressure pipes, to admit of the speed and power being suitably controlled.

Amongst the many other efficient forms of turbines in use may be mentioned the Fromont, Fourneyron, Thompson, Vortex, Francis, Risdon, Little Giant, and the Victor.

Where a very high head and limited quantity of water is available, and the ordinary forms of turbines, or water wheels, would be practically useless, the Pelton water wheel might be employed.

In some cases an ordinary overshot water wheel, or a Poncelet undershot water wheel would be found to be suitable.

ELECTRIC MOTORS.

An electric motor is a machine or apparatus which converts electric energy into mechanical kinetic energy. As a general rule

the electric energy is of the dynamic or current type, and electric motors of the current type are of two sorts, viz., direct current and alternating current motors. The first of these are usually constructed in a manner practically similar to dynamos, and they may be either series wound, shunt wound, or compound wound, or of the magneto type, a fixed field being provided in the latter case irrespective of any current sent through them.

Direct Current Motors.

The following particulars given in "The Standard Electrical Dictionary"* briefly explain the principles involved:—"A current passed through a magneto or motor with separately excited field will turn it in the direction opposite to that required to produce the same current from it were it worked as a generator.

"A current passed through a series wound motor acts exactly as above. Both these facts follow from Lenz's law.

"A current passed through a shunt wound motor acts oppositely to the above. The direction of rotation is the same as that required to produce a current of the same direction. This is because, the field being in parallel with the armature, the motor current goes through the magnet coils in the direction the reverse of that of the current produced in the armature when it is used as a dynamo. Hence this also carries out Lenz's law.

"The compound wound motor acts one way or the other, according as its shunt or series winding preponderates. The two may exactly balance each other, when there will be no motion at all. The series connections of a compound wound dynamo should therefore be reversed, making both series and shunt work in unison, if the dynamo is to be used as a motor.

"The general principles of the electric motor of the dynamo, or continuous rotation type, can be only outlined here. The current passing through the field magnets polarizes them and creates a field. Entering the armature by the brushes and commutators it polarizes its core, but in such a way that the north pole is away from the south pole of the field magnet, and the same for the south pole. Hence the armature rotates. As it does this the

* "The Standard Electrical Dictionary," by T. O'Conor Sloane, A.M., E.M., P.D., 2nd Edition (London: Crosby Lockwood & Son).

brushes connect with other commutator sections, and the poles of the armature are shifted back. This action continues indefinitely."

A polyphase, multiphase, or rotatory current motor is one which is arranged for the distribution of the multiphase currents in coils symmetrically mounted around the circle of the field. These coils are wound on cores of soft iron, a rotating field being produced in this manner, and a permanent magnet or a polarized armature pivoted in this field will rotate with the field, its poles following the poles of the rotatory field.

Alternate Current Motors.

The subjoined short description abstracted from Fowler's "Pocket Book"* gives a very clear idea of the principle upon which this type of motor works:—

"Alternate current motors are of two classes:

1. Synchronous motors } Single and polyphase.
2. Asynchronous motors }

"Synchronous motors are, as their name implies, those that run in exact accord with the varying phase or alternations of the alternating current. For example, two similar single phase alternators in series, one being driven as a generator will drive the other as a motor at the same speed as itself exactly, if the second one be first run up to the speed so that its own alternations are the same as those of the generator. It would then be possible to load the motor up to full power without throwing it out of synchronism.

"A synchronous motor, then, has a set of field magnets separately excited by a continuous current, its armature being fed by an alternating current, which, if single phase, will necessitate the armature being run up to speed by external means before load is put on. It is, therefore, not self-starting without special devices.

"With polyphase currents, however, it is possible, by sinking conductors in the field magnets, to make the rotating field, due to the polyphase currents, start the motor and run it up to speed, by which a self-starting motor is obtained which runs under load in perfect synchronism with the supply."

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* Fowler's "Mechanical Engineer" Pocket Book, 1900 (Manchester: The Scientific Publishing Company).

"*Asynchronous Motors.*— In these the rotation of the motor is produced by action of the rotating magnetic field on the induced currents in the conductors buried in the motor. This induction is due to the fact that the motor does not run in synchronism with the rotating magnetic field due to the alternating current. These motors do not require either commutators or slip rings, the motor being entirely detached electrically from the field magnets and the outside supply circuit.

"Asynchronous motors may be either single-phase or polyphase, usually the latter. They are started under load with high-starting torque, and their efficiency is quite equal to that of the continuous current motors.

"It is the development of these high current motors to such a high pitch of mechanical and electrical efficiency which has rendered the long-distance transmission of power economically possible."

Wind Motors.

As has been already mentioned, wind power is of too uncertain a nature to render it of any great value for main driving purposes. For working a pump employed for raising water from a river to a storage tank or pond, or from a pond situated at a low level to one at a higher level, and for drainage or irrigation purposes, or indeed for any service where only comparatively small power is required, and its possible intermission is not a matter of vital importance, it may, however, be advantageously employed.

The best form of windmill or wind motor to employ for this service would be one of the American type with metal vanes or sails.

The following hints will be of use to those thinking of employing this power. The shaft of the wind motor should be so set as to be at an elevating angle with the horizon, when located upon ground at a low level, and at a depressing angle when located upon high ground, the range of angles running from 3 to 35 degrees. Wind having a velocity of 10 feet per second will not as a rule be found sufficient to work a loaded wind motor, whilst on the other hand a velocity of over 25 feet per second will be found too great for the usual run of structures.

The length of the whip or radial arms of the sails of wind motors for pumping water or similar duties is about five times

their breadth, the sails being rectangular in shape. Four, five, or six sails may be used, bearing in mind that the entire sail surface must not be more than a quarter of the entire disc surface described by the whip or radial arms of the sail, and the weather or wind board should be about one-fifth of the sail's breadth. The sails should be held at the following angles, commencing from the shaft centre, viz., 24, 21, 18, 14, 9, and 3 degrees from the plane of motion.

In order to utilize the maximum amount of the impulsive effect of the wind to produce rotary motion, seven-eighths of the surface of the circle formed by the motion of the sails should be presented to the wind, and according to Smeaton's rule each sail should be angled to the plane of motion in the following manner, the whip or back being divided into six equal parts:—

Distance from centre of motion	1	2	3	4	5	6
Angle with plane of motion .	18°	19°	18°	16°	12½°	7°

The same authority gives the following deductions from velocities varying from four to nine feet per second:—

1. The velocity of windmill sails, so as to produce a maximum effect, is nearly as the velocity of the wind, their shape and position being the same.

2. The load at the maximum is nearly as, but somewhat less than, the square of the velocity of the wind, the shape and position of the sails being the same.

3. The effect of the same sails, at a maximum, are nearly as, but somewhat less than, the cubes of the velocity of the wind.

4. The load of the same sails, at the maximum, is nearly as the squares, and their effect as the cubes of their number of turns in a given time.

5. When sails are loaded so as to produce a maximum effect at a given velocity, and the velocity of the wind increases, the load continuing the same—first, the increased effect, when the increase of the velocity of the wind is small, will be nearly as the squares of those velocities; secondly, when the velocity of the wind is double, the effects will be nearly as 10 to 27½; but, thirdly, when the velocities compared are more than double of that when the given load produces a maximum, the effects increase nearly in the simple ratio of the velocity of the wind.

6. In sails where the figure and position are similar, and

the velocity of the wind the same, the number of revolutions in a given time will be reciprocally as the radius or length of the sail.

7. The load, at a maximum, which sails of a similar figure and position will overcome at a given distance from the centre of motion will be as the cube of the radius.

8. The effects of sails of similar figure and position are as the square of the radius.

9. The velocity of the extremities of Dutch sails, as well as of the enlarged sails, in all their usual positions when unloaded, or even loaded to a maximum, is considerably greater than that of the wind.

CHAPTER XVI.

FINAL TREATMENT OF THE TEA.

Mixing, Blending, or Bulking Machines—Movable Container Machines—Machines with Movable Arms or Agitators—Combined Movable Arm or Agitator, and Movable Container Machines—Packeting or Parcelling Machines.

THE final or last operations to which the finished tea is subjected are those of mixing, blending, or bulking, and of packeting or parcelling for retail distribution.

MIXING, BLENDING, OR BULKING MACHINES.

A large number of machines have been devised for the above purpose, the major portion of which operate on one or other of three principles, viz.:—those in which the tea is placed in a movable container, the rotary or reciprocating motion of which produces the desired effect; those wherein the tea is placed in a fixed or stationary container, and the mixing is performed by arms, vanes, or agitators, arranged to rotate or move within the casing; and, lastly, those in which a combination of movable container and movable arms or agitators is provided for mixing the tea.

The following are a few of the mixing or bulking machines that have been devised.

MOVABLE CONTAINER MACHINES.

A machine for this purpose, designed by C. H. Bartlett, consists of a drum mounted upon trunnions, and provided with internal spiral ribs, which carry the tea along into radial chutes adapted to deliver it into an inclined discharge spout or chute fitted in the lid of one of the trunnions.

This discharge chute is provided with an inverted V-shaped

slide, by which the entry of the tea is prevented until it is sufficiently mixed.

To carry back the tea from the delivery end of the drum to the other end, one or more spiral blades are fitted internally and inclined in the opposite direction to the blades.

Another apparatus designed by the same gentleman comprises a drum formed at one end with an axial discharge opening, through which the tea may be discharged by means of a chute formed in two parts, the one fixed on a tube and the other on a rod, which may be moved axially. In one position the tea carried up by the inclined blades is dropped into the chutes during the rotation of the drum.

The neck of the drum is supported on friction rollers, and the latter is connected by gearing to a winch handle.

A machine invented by D. Burr comprises a drum, to which a slow rotary movement is imparted, and which has fixed to its sides lifters so arranged that those on one side will carry up a portion of the tea and deliver it across to those on the other side, and so on. These lifters are also adapted to discharge the contents through the mouth when the lid is removed.

A machine devised by W. Parnall consists of a drum provided with internal vanes, and so mounted in a frame as to be readily rotatable. In this drum are peripheral openings provided with doors, which may be used for charging and discharging, and with side openings diametrically opposite to each other, the one fitted with a door hinged towards the centre of the drum being intended for charging, and the other having a door hinged at the periphery, and intended for discharging.

Another machine designed by the same gentleman consists of a sheet-iron vessel, or drum, rotatably mounted in a suitable framing, and provided with a charging aperture, which is normally closed by means of a sliding door. This drum is traversed by a shaft carrying a number of metal plates or tongues, or these latter are attached internally to the sides or ends of the drum.

The tea dust is retained in the mixing cylinder during the operation by means of sheet-iron plates bolted to the framing, and a cover resting thereon over the drum.

An apparatus for the purpose in question, which is also

adapted for sifting and cutting, devised by W. Gilbert, has a series of oscillating hoppers, the mouths of which can be opened or closed by a register plate working between a pair of fixed plates. The rate of feed from each of these hoppers can be adjusted by means of fish-head valves placed opposite to the openings in the lower plate. From these hoppers the tea falls on to a series of rotating discs, from which it will be thrown on to conical shelves, and finally passes into a suitable receptacle.

The sifting and cutting are performed in separate devices contained in the same frame, the former by an arrangement of shaking sieves, and the latter by cutting rollers.

In a machine designed by B. Tupholme, the tea falls upon a travelling band, by which it is conveyed to a mixing cylinder containing three canted wings and two bayonet-sided trihedrons, which, it is claimed, will effect the mixing or blending by a few revolutions of the drum.

The door of the drum can be opened by a pair of racks, which can be put into gear by two pinions on shafts above and below, operated respectively by a pulley with an endless rope, and a hand wheel.

From the mixing drum the tea glides gently into troughs, into which scoops fit easily; or it may be delivered into a chest by a travelling belt.

For delivery into bins on the floor below, a receiver or carriage is used having four triangular doors in the bottom supported by chains. The carriage is run over a hopper containing sliding doors, so that any one of the four bins may be filled.

In an apparatus devised by A. H. Hobson, the tea is mixed in an inclined revolving drum having two sets of cross partitions, so arranged with regard to one another that, as the drum revolves, the tea will be transferred from one set of partitions to the other, and traversed in a zigzag fashion through the drum.

The material is fed by a hopper into the upper end of the drum, and is discharged from a chamber at the lower end by means of a weighted door.

The partitions are sometimes pivoted, so that they may have their inclination adjusted as desired, and they are secured in position by set screws, so as to facilitate their removal for cleaning.

P. H. Bracher employs a polygonal receptacle fixed on a shaft provided with collars, and mounted in a frame or casting. Beaters are fixed to the sides or ends of the receptacle, or to the shaft. The receptacle is fitted with a door, through which the contents are emptied into a drawer, baffle plates being provided for spreading the material therein. The upper part of the casing is made removable.

An apparatus designed by E. Burke consists of a rotatably mounted cylinder, having internally a number of shelves arranged around it, and forming an acute angle with the circumference of the cylinder, centrally in which latter is placed a disc attached to the ends of the cylinder, and fixed at an angle to the central shaft.

Upon the cylinder being rotated, the tea will fall from shelf to shelf, and, by the action of the above-mentioned disc, will also be thrown from end to end of the cylinder.

Another machine proposed by the same gentleman consists essentially of a chamber having a number of longitudinal shelves fixed to its ends. This chamber is arranged to rotate on a diagonal or eccentric axis, so that the tea will be thrown from end to end during the rotary motion. The mixed tea is discharged into a hopper beneath the mixing chamber, from which it can be removed through several spouts.

In a machine invented by A. E. Jarvis and others, the tea to be mixed is placed in a hopper, from which it will fall in a divided stream over inverted V-shaped, or roof-shaped, arrangements of boards into funnels located beneath them, finally passing into another hopper.

The entire apparatus is so mounted on trunnions that it can be reversed, and the tea caused to pass any desired number of times through the mixers.

A machine designed by R. H. Broom consists of a square or other suitably shaped box, fitted internally with cross bars to break up the tea. This box is so mounted on trunnions fixed diagonally at opposite corners as to be free to rotate thereon, and it is also fitted with a sliding lid or cover on one side, for filling or emptying.

A hand crank is provided for turning the box, and the standards upon which it is supported are hinged or jointed to the bed,

or base plate, thus admitting of their being folded down for convenience of packing.

A machine proposed by A. Carson comprises a large hollow drum rotatably mounted on a horizontal shaft, and divided into two parts by an opening extending round the periphery. Round this opening a band of leather or sheet-metal is stretched, being carried back over two guide pulleys near the top, so that an open space is left for introducing and discharging the tea. Inside the drum are radial spokes fixed in an inclined direction, and longitudinal plates are arranged inside the casing to raise the tea from the bottom to the top.

To discharge the mixed tea, the above-mentioned band should be either loosened or moved to one side, or the location of the opening may be changed by moving round the guide pulleys.

The frame holding the pulleys for the strap is held by a brake block, and oscillating doors are fitted in the annular opening round the drum.

In a machine devised by J. Dick, the tea is carried round by radial compartments towards a central chute. The casing is made in tiers and bolted together, each tier being divided into a series of triangular compartments with inclined sides, and the narrow ends pointing towards the central chute. In the outer wall of each compartment an opening is provided, and a hopper fitted externally, and the bottom of each compartment has a jigging motion imparted to it from a central shaft actuated by a cam.

The openings from the compartments can be regulated by raising or lowering the central shaft by a screw on the cam frame.

A machine designed by B. Tydeman consists of a revolving mixing drum or cylinder provided on its periphery with trays opening outwardly, and with openings, or apertures, which are normally closed by sliding doors, leading into suitable chutes. The drum or cylinder is fitted internally with six sets of helical rods, arranged alternately left and right, four of the sets containing shelves, and it is also fitted with linings, sloping so as to form a hopper.

The drum or cylinder is driven through a worm wheel and worm, and the tea is raised to a platform, from which it is emptied into the trays, and thence into the drum.

After mixing, the tea will pass through the sliding doors and be conducted by chutes into chests placed on scales ready for weighing.

A machine designed by J. Bartlett is so arranged that the broken or reduced tea will be delivered from the cutting mill, the latter, together with its hopper, being located at one side of the mixing drum, instead of over the top, so as to reduce the head room required. The cast end of the frame carrying the drum is bolted to the side framing, and the chute is pivoted to this latter in such a manner that it can be adjusted by means of a wheel or handle, to deliver into the drum.

The receiver, into which the mixing drum discharges, is provided with a fall-down front, which can be converted into a drawer when desired, by locking the front up to the sides by means of a shutter bar engaging in staples on the side frame.

A machine designed by L. Malone comprises a closed cylinder containing a series of spiral-shaped shelves, by which, when the cylinder is rotated on its axis by a crank or hand wheel, the tea will be thrown in both longitudinal and tranverse directions.

In a machine devised by W. Greeves, two chambers are provided, arranged to communicate with each other through an opening, which can be closed by a slide at the apexes of two abutting funnel-shaped or conical bottoms. One of these chambers is provided with an opening for the insertion and removal of the tea.

These chambers are supported in a frame on a standard by trunnions or gudgeons, and the mixing is performed by the repeated reversal of the motion of the frames.

In a machine invented by Hogg and Donovan, the tea is placed in a box mounted on trunnions or gudgeons in a frame. The four sides of this box are perforated, and are covered with double sieves, or gratings with corresponding perforations. The vertical sides are kept closed by sliding the sieves, so that the perforations thereof do not coincide whilst the perforations on the top and bottom sides are opened, so as to admit of the tea falling through into buckets in a revolving drum or cylinder, which carries it from the bottom and delivers it at the top.

The top plate is reciprocated by cams to open and close the top side of the box. When this latter side is closed, the tea will

be deposited on the top of the box by the buckets, and there evenly spread by curved arms. The lowermost of the upper sieves being then lowered, the tea will fall in a partly mixed condition in layers into the box. The lower sieve on the bottom of the box can be moved downward into position by a lever operated by a cam or eccentric, the two shafts carrying the curved arms passing through the box and being separately driven by gearing from the driving shaft, which latter carries a pinion gearing with teeth on the rotating drum. The box is mounted on trunnions, and a quarter turn is given to it to bring the horizontal sides into a vertical position, when, after gearing up the curved arm shaft and adjusting the perforated plates, the operation is repeated as before.

An apparatus designed by W. Thompson consists of a mixing drum mounted on a shaft, and arranged to be driven by belt gearing. In this drum are provided radial and other sieves, the latter being so arranged as to form the sides of a polygon, and mounted on hinged joints to allow of their being folded back to facilitate the removal of the mixed tea, or the sieves are arranged to slide in grooves in the side of the drum for a like purpose. The drum is charged and discharged through flexible chutes, and when it is desired to discharge the tea, one of the radial sieves, adjacent to the discharge chute opening, is covered with a board, so as to cause all the tea to collect in one compartment.

Machines with Movable Arms or Agitators.

A machine, designed by J. and F. Hamilton, comprises an elevator of the bucket type, by which the tea will be automatically delivered from a hopper into a chamber having perforated walls, in which it is mixed by revolving arms or blades, the tea dust being at the same time carried away through the casing by means of a fan and discharged through a chute, and the mixed tea being delivered through another chute from the machine.

A machine, devised by J. and J. A. Baker, consists of a receptacle provided with a removable sieve bottom, and fitted with a shaft adjustable in slots, and carrying a set of agitators which work between a second set fixed to a tube. The above-mentioned

agitators are oscillated in opposite directions through cranks and rods connected to a crank-pin on a fly-wheel.

A suitable hopper is provided for the reception of the tea, which hopper is fitted with teeth, or projections, and a toothed cutting or mixing roller. The tea is fed through an opening into the mixing receptacle where it is operated upon by the agitators, the finer tea passing through a sifting surface into a drawer provided for the purpose, and the remainder, which consists of the mixed tea, being discharged into another drawer by tilting over the mixing receptacle by means of a handle, or of a cord or chain passing over pulleys.

This apparatus can be employed as a mixer only, the cutting or breaking roller being dispensed with in this case, or it may be used for sifting only, in which case but one set of agitators is employed.

In a machine designed by W. Harvey, a cylindrical chamber provided with a funnel, and containing a fly-wheel fitted with radial vanes and a conical shield having blades, both of which can be rotated by a hand-wheel, are provided.

The funnel is divided into compartments to receive the various kinds of tea to be blended, which compartments communicate with a central tube, in which an inner tube is arranged to slide for regulating the discharge of tea into the mixing chamber beneath. This latter is provided with an inclined or funnel-shaped bottom, having a flange to fit the mouth of a tea canister. A sieve to receive the tea before its entry into the mixing chamber is sometimes also provided.

Combined Movable Arm or Agitator, and Movable Container Machine.

An arrangement of apparatus devised by J. Richards, consists of a mixing cylinder, into which the tea is fed by means of a hopper secured to the floor, forming the bottom of a tub, which latter is fed from a tray by removable bins, the size and form of which, or of mouthpieces attached to which, regulate the supply.

The tea is partially mixed in the above-mentioned tub by an agitator, consisting of a central boss having outwardly extending arms, over which is arranged a plate which has divisions

corresponding to the arms of the agitator, and is rotated from the working shaft through toothed gearing and a suitable spindle. This plate serves to regulate the admission of the tea to the tub, and to prevent any undue pressure on the agitator.

For the regulation of the admission of tea to the hopper, the bottom of the tub, and that also of a plate immediately above it, are similarly divided to the other plate, and are so arranged as to be adjustable by hand, so as to close, or partly close, the divisions in the tub bottom.

The mixing cylinder is rotated on a horizontal shaft by means of belt gearing, and is provided internally with arms which assist in the mixing.

The mixed tea is delivered through the opposite open end of the cylinder to a conduit, and thence in quantities regulated by the damper into a chest.

Tea Packeting or Parcelling Machines.

The packeting or parcelling of tea for retail distribution being a very important operation, and one which, when carried out by hand labour solely, entails a vast amount of labour, inventors have naturally been prompted to devise machines which will perform the work in a more or less automatic manner.

These machines are usually designed to deliver the tea into, and to produce folded packets in paper, lead, tinfoil, or other suitable material. The most practical type of machine of this class is that in which the pocket or empty wrapper is first placed or formed on the stem of a funnel, is then closed at the bottom and placed in a mould or former, the funnel and mould corresponding internally with the shape of the finished packet, the tea to be packed being then placed in the funnel and consolidated or forced into the pocket by a rammer. The funnel is next withdrawn, followed immediately afterwards by the rammer, leaving the packed pocket in the mould, and that portion of the wrapper projecting above the mould is then folded over, and the completed packet pressed out of the mould or former.

Of the many machines and apparati that have been designed, the following are the principal:—

An apparatus, invented by B. H. Watson and others, provides

for the withdrawal or lifting of the funnel by vertically moving rods, and the transferring of it by a carrier of peculiar construction. This is effected by a pendant carrier provided at the bottom with spring fingers or the like, and at the top with a roller running on a rail conveniently placed overhead. One end of this rail is pivoted to a fixed point at the side of the machine, the other is capable of a vertical movement, so that the rail may be tilted one way or the other to cause the carrier to roll along towards or from the fixed point. This vertical movement is set up by a pendant arm on the moving end of the rail, or by the rail itself coming into contact at suitable times with the rammer or parts connected with it. A pin or projection retains the rail in its highest position until liberated by the mechanism. When the funnel and mould are in position in the machine, the rammer in moving downwards will liberate the rail, allowing it to descend far enough for the carrier to roll towards the mould, and the spring fingers to engage with the funnel. When the rammer ascends, it will lift the rail, the amount of elevation finally attained being sufficient to cause the pendant carrier to roll away to the fulcrummed end of the rail. Just before it reaches this point, the funnel will come into contact with a fixed abutment, which pushes it off on to a suitable frame or holder, from which it may be removed by hand or otherwise.

For folding over the projecting portions of the wrapper, doors or slides, so operated as to fold it over from different sides, are provided, the production of a neat finish being facilitated by a device which comes into action after one or more folds have been made, and presses or creases some of the upstanding doubled portions tightly together.

To fold square packets from the four sides, for example, the first fold is made with a door or plate of thin flat metal, and the remaining ones, either by other doors or slides in the case of machines with fixed moulds, or by stationary doors or grooved guides in the case of machines with moving moulds. Where four doors are employed, the doors are caused to slide at due times across the top of the mould by leaders and cams or other mechanism. The first door is so guided that in advancing to make a fold it will rise up a little, and then descends on to the wrapper. The creasing of the upturned doubled edges is effected

by two arms which sweep around a horizontal axis arranged adjacent to one side of the mould. Each arm is constructed in two pieces pressed together by springs, the upturned doubled edges of the wrapper passing between these pieces, and being pressed tightly together by the springs as the arm sweeps round. The second door, which is mounted similarly to the first, next advances, and folds down the opposite side of the paper. The formation of the packet will be facilitated by one or other, or both of these doors, remaining in position until the folding has been completed. Finally, the side doors advance and finish the folding, and the packet is pressed out after all the doors have been withdrawn.

The pressing or creasing arms are preferably actuated through a coiled spring compressed by some convenient part of the driving mechanism, the arms being held inoperative by a detent until required to act. When this detent is released, the axle makes a rapid revolution, and is then again caught by the detent, and held until the next cycle of operations.

When the moulds are caused to move to and from the ramming position, the first fold is made and the edges creased as above, the remaining folds being made either by doors or otherwise. For example, the mould may be caused to pass under a stationary door or presser to make the second fold, and cause the side flaps or upturned edges to enter grooves in a fixed piece, these grooves being inclined so as to bend over and fold the wrapper as the pocket passes underneath. Or the mould may remain stationary whilst the grooved piece is made to slide over it.

A simple pattern of machine has a single fixed mould mounted on a table, and provided with mechanism actuated by a shaft underneath. Funnel-withdrawing, and folding and creasing devices, are provided, and also a suitable automatic stop arrangement, by means of which the mechanism can be caused to come to rest after a complete cycle has been performed. This can be conveniently effected by driving the shaft which sets in motion the various mechanisms by a clutch and gear put into action by a handle, treadle, or the like. This motion compresses a spring, or lifts a weight, which is held or locked until automatically released, at the end of the cycle of operations, by some part of the mechanism, when the spring or weight then acts to withdraw the

clutch. This disengaging mechanism is applicable also to other forms of packing apparatus.

A machine for packing tea, of the pattern under consideration, is illustrated in Figs. 206 to 217.

Figs. 206 and 207 show the funnel mechanism, *a* being the

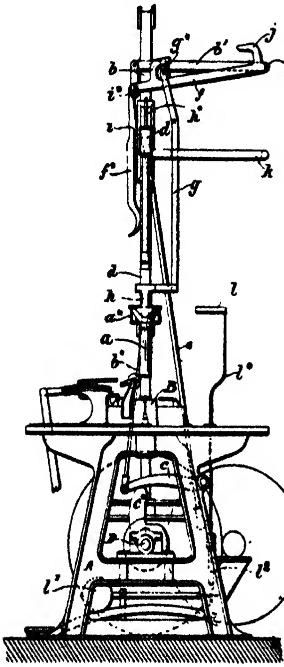

FIG. 206.—Tea Packeting or Parcelling Machine (side elevation showing the funnel mechanism).

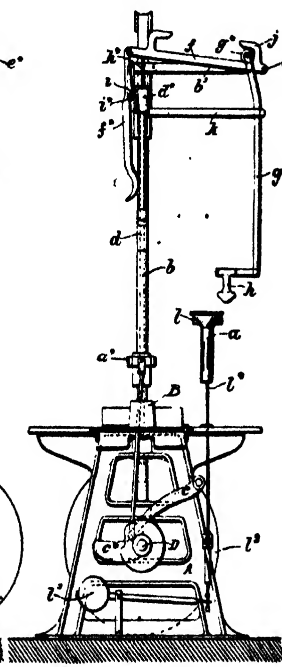

FIG. 207.—Tea Packeting or Parcelling Machine (side elevation, partly in section, showing the parts in a different position).

funnel, which is carried by a forked holder a^* arranged to slide up and down a fixed rod *b*, and connected by a rod b^* to a lever *c*, acted upon by a cam or wiper c^* on the main shaft D, which is rotatably supported on the frame A of the machine. *d* is the rammer which is carried by a cross-head d^* sliding on the fixed rod *b*, and is moved by the connecting rod *e*. The top of the

fixed rod b is provided with a projecting arm b^1 carrying a pin e^*, to which is pivoted the rail f of the funnel discharger, the other end of this rail being free to move up and down, and having a pendant arm f^*. This rail supports the funnel-carrier g, which is provided at one end with a roller g^* to run on the rail, and at the other end with spring fingers h for engaging with the funnel. The carrier g rolls backwards and forwards along the rail f as the end of the latter is raised or depressed, the former being effected by a rod h^* on the crosshead d^* when the rammer is raised to its highest position, the rail being retained by a tooth i on the pendant arm f^* dropping on to a pin i^* carried from the fixed frame; and the depressing being effected by gravity as soon as the rammer-crosshead d^* descends low enough to engage with the curved part provided at the free end of the pendant arm f^*, and push the tooth i off the supporting pin i^*. The mechanism is shown at rest in one position, with the rail f depressed just before the lifting commences, in Fig. 206, and raised and supported by the pin i^*, in Fig. 207; j are horns on the rail f, and k is an arm provided with stops, and carried by the crosshead d^*, for limiting the motion of the carrier g.

The funnel is received after a discharge by a forked frame l, which arrests it as it moves away and allows the spring fingers h to clear it, as shown in Fig. 207, after which it drops down into the position shown.

For greater convenience in removing the funnel from the frame l, this latter is mounted on a rod l^* slightly overbalanced by a weighted lever l^1, so that the additional weight of the funnel will cause the rod l^* to descend. The lower end of the rod l^* is provided with a pin sliding in a helical slot in the fixed holder, so that the descent of the part l^2 will cause the forked frame l to partially revolve, about a vertical axis, into the position shown in Fig. 207. Upon the removal of the funnel the weighted lever will return the forked frame to the position shown in Fig. 206.

The wrapper is folded over by doors or slides mechanically moved so as to operate upon it from different sides in any desired sequence, the production of a neat finish being facilitated by a pressing or creasing device, which comes into action after one or more folds have been made, and presses some of the upstanding doubled portions tightly together. To fold square packets from

the four sides, the first fold is made with a door or plate of thin, flat metal, and the remaining ones either by other doors or slides, in the case of machines with fixed moulds, or by stationary doors or grooved guides in the case of machines with moving moulds.

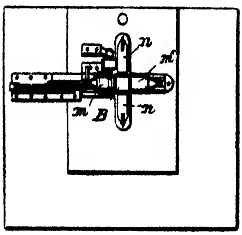

FIG. 208.—Tea Packeting or Parcelling Machine (plan of folding and discharging device).

The four-side folding mechanism is illustrated in Figs. 208 to 215. B is the mould intended to contain the filled packet, and arranged so that four plates m, m^*, n, operated by springs and by cams on the main shaft D in any desired sequence, can slide over the top from the four sides. The plates m and m^* are connected to the tops of levers o, p pivotted at o^*, p^* to the frame, and pressed towards each other by springs q when liberated by the cams r, r^*.

The levers are returned to their normal position by the same cams when the folding is completed. The plate m^* is secured to a sliding piece connected to the operating lever p, and having a pin or projection s^*, which slides up an inclined plane s^1 as it moves towards the packet, and drops over the end of this plane when it reaches the extreme limit of motion in this direction. By this means the plate m^* is tilted up as it advances, so as not to injure the wrapper of the packet, until it is fairly over the mould, when it drops and presses the wrapper down firmly, the degree of pressure being determined by a spring p^1 stretched across from the lever p to the sliding piece at or near the projection s^*. [illegible]kward stroke this projection s^* passes under the plane

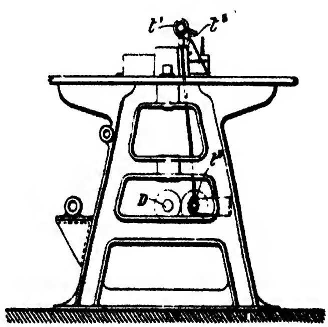

FIG. 209.—Tea Packeting or Parcelling Machine (side elevation of folding and discharging device).

s^2, which is pivoted at s^3, and provided with a spring and lever to return it promptly to its normal position after the projection s^* has passed it. The plate m is similarly mounted and operated. The side doors or plates n are connected to levers n^* having inclined planes n^1 engaging with rollers on arms n^2, connected with a cam arm q^*. The levers n^* are drawn together by springs. q^{**}, and are liberated and re-set by cams. These plates n are hinged to the tops of the levers n^*, and are provided with springs n^{**}, by which the pressure is determined.

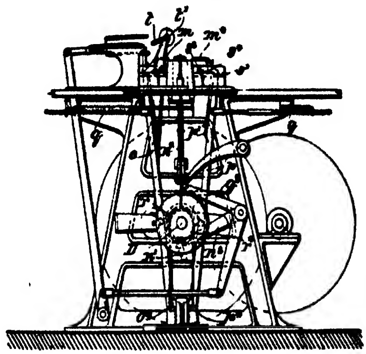

FIG. 210.—Tea Packeting and Parcelling Machine (sectional side elevation of folding and discharging device).

As soon as the plates m and m^* have folded over their portion of the wrapper, and before the plates n come into operation, the upturned edges of the wrapper are creased by means of two spring fingers or creasers t mounted on a suitable spindle, and arranged to sweep around a horizontal axis. Each of these creasers t is constructed in two pieces, which are pressed together by springs t^* (Fig. 212), the upturned edges of the wrapper passing between these pieces, and being pressed tightly together by the springs as the arm sweeps round. They are driven by a coiled spring in a case t^1, which is wound up

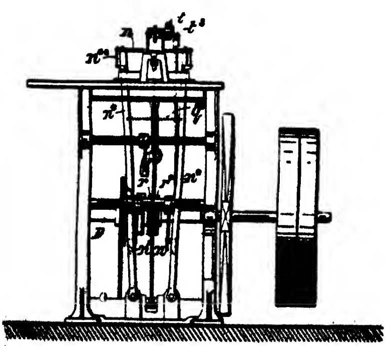

FIG. 211.—Tea Packeting and Parcelling Machine (end elevation of folding and discharging device).

continuously by mitre wheel gearing t^2, receiving its motion from the main shaft D. A spring detent t^3 retains the creaser spindle until it is tripped by a projection o^1 on the lever o. The creaser spindle then makes a revolution, and is arrested by an arm or projection t^{1*} on its coming into contact with a spring buffer t^{2*} carried by the lever o. On the return motion of the lever o this arm or projection will be released, the spring detent dropping into its place and holding the creaser spindle until the next advance of the lever o.

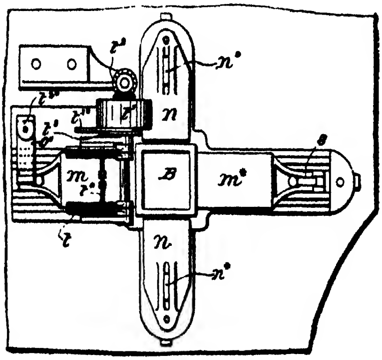

FIG. 212.

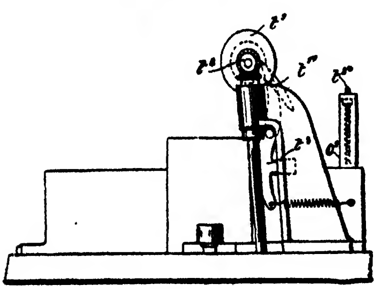

FIG. 213.

FIGS. 212, and 213.—Tea Packeting or Parcelling Machine (detail views of folding and dischaging device).

When the moulds are caused to move to and from the ramming position, the first fold is made and the edges are creased in the manner above described, the remaining folds being made either by doors or otherwise. For instance, the mould may be made to pass under a suitable stationary door or presser to make the second fold and cause the side flaps or upturned edges to enter grooves in a fixed piece, these grooves being inclined in a suitable manner to bend over and fold the wrapper as the packet passes underneath. Or a stationary mould may be used, and the grooved piece be arranged to slide over it. It is frequently found advantageous to fit a machine

this class with a starting and stopping mechanism, so that after a cycle of operations has been performed it will come automatically to rest. A method of accomplishing this object is shown in Figs. 216 and 217, in which arrangement the gearing is driven through a clutch *u* operated by a lever *v*, one end of which is connected to the starting and the other to the stopping mechanism. The starting mechanism consists of a treadle *w* connected through a lever *x*, rod x^*, rocking shaft x^1, and bell-crank x^2 to the clutch lever *v*.

The stopping mechanism consists of a spring *y* acting on a lever y^* when released by a cam y^1, and by means of a bell-crank *z* and bar z^* pushing sharply against the end of the clutch lever *v*.

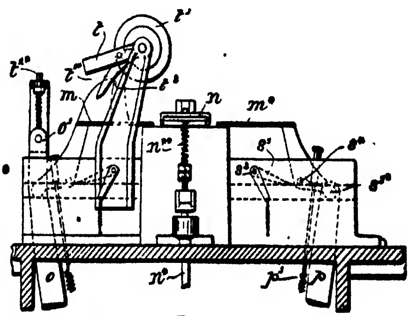

FIG. 214.

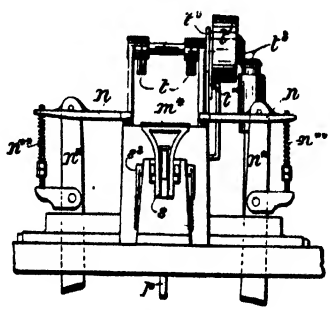

FIG. 215.

FIGS. 214, and 215.—Tea Packeting or Parcelling Machine (detail views of folding and discharging device).

In order to prevent the stopping interfering with the starting arrangements, a pin is provided in the end of the bar z^*, which, when in action, travels over a flap z^1, so as to retain it in contact with the lever *v*, but which, as soon as it has accomplished its travel, will drop down clear of this lever, and will return under the flap z^1, which latter is hinged at z^2, and is provided with a spring z^3 to allow of its regaining its normal position.

The treadle *w* may be replaced by some form of hand-actuated mechanism, if desired.

Fig.* 218 illustrates another type of patent tea packeting or parcelling machine, of which the Pulsometer Engineering Company, Ltd., are the sole licensees and makers. This machine is, as will be seen from the drawing, of a very simple form of construction. The arrangement of the funnel, and of the rammer or plunger, are clearly shown, and as the packing is effected by a single stroke of the latter, the tea is not broken up into dust, an advantage which is of no small importance, inasmuch as the excessive formation of dust produced by the repeated blows of the rammer in hand packing, and in some forms of tea packeting or parcelling machines, constitutes a serious loss.

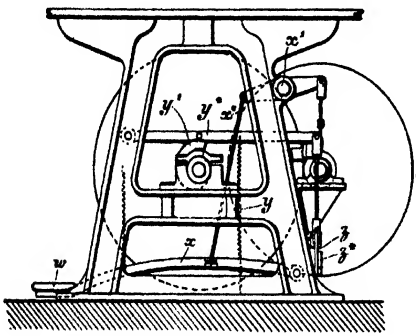

FIG. 216.—Tea Packeting or Parcelling Machine (side elevation of starting and stopping device).

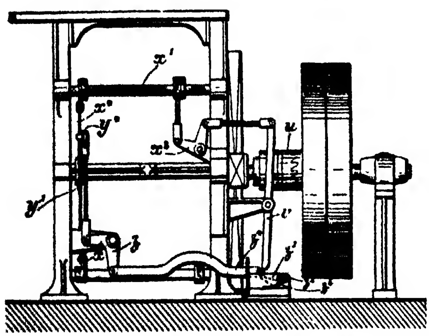

FIG. 217.—Tea Packeting or Parcelling Machine (end elevation of starting and stopping device).

This machine allows of from eight to ten half-pound packets of tea being made per minute with the standard size machine. Moulds and funnels are, however, also supplied with each machine, enabling two-ounce and four-ounce packets to be made by the same apparatus as well as the half-pound packets already mentioned.

The following are brief descriptions of some of the other tea packeting or parcelling machines that have been designed.

A machine invented by J. Skinner comprises a table which is caused to revolve intermittently on ball-bearings, and carries four receptacles with inner chambers for the reception of the packets.

At the first stage of the operation a funnel with the packet around it is placed in a box. At the second stage the packet is filled with tea, and at the third stage the flange of the funnel slides into a recess in an arm which raises it out of the packet to the level of the guides, where it is knocked out of the recess in the arm by a horizontal lever on to the guides, down which it slides to the front of the machine. Before the funnel is lifted the rammer descends and compresses the tea in the packet.

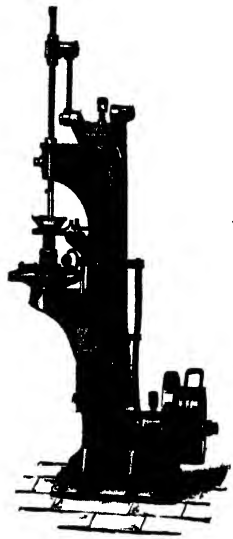

Fig. 218.—Single Stroke Tea Packeting or Parcelling Machine (perspective view).

Between the third and fourth stages of the operation four rods pass successively over cams on the table, which, by raising them, operate the plates and cause them to press down the flaps of the packet. At the fourth stage the hinged bottom of the above-mentioned box, which has hitherto been held up by its sliding over a cam on the table, is permitted to fall, and is pushed out of the box and through a hole in the table under the action of a plunger.

The packet is then pushed out of the machine by another plunger, operated by a cam. The bulk of the mechanism is inclosed in a casing.

A machine devised by S. Learoyd has the following devices for weighing and packeting:—During half of a revolution of a shaft the tea is arranged to pass from a suitable hopper into a measuring space between plates, until a cam, by striking an arm, causes the lower plate to uncover an opening, and allow the tea to fall into a scales, the difference being supplied by causing the upper plate

to oscillate, and admitting of the tea being fed into the scales directly from the hopper.

The descent of the scales will close an electric circuit, and energize an electro-magnet, the armature lever of which receives the lower measuring plate and allows it to return to the closed position under the action of a coiled spring, a further rotation of the driving shaft causing a cam to tip the scale pan through the agency of an arrangement of links, the weighed portion of tea then falling into the bucket of a conveyer ready for packing.

During this weighing operation a length of paper has been fed from a roll through straightening rollers on to a table, and the required length cut off by a knife. A hollow plunger attached to a band now descends, under the action of segmental gearing, upon a suitable shaft, and presses the piece of paper into a box-like shape, and at the same time the descent of the plunger will act through a cord to tilt the conveyor bucket so that its contained charge of tea will be delivered through a chute, and the above-mentioned hollow plunger, into the paper receptacle.

A further rotation of the driving shaft raises the hollow plunger and returns the bucket for a fresh charge, whilst various presser arms, operated by cams, fold the end, sides, and top of the paper into shape, the completed packet being finally pushed out of its slide so as to allow of the various folders returning to their normal positions in readiness for the next packet.

A machine for filling and packeting tea, designed by J. Howard, comprises a funnel into which the packet to be filled is inserted, and is placed in a mould. A skeleton rammer is then placed in the funnel, and the contents of the packet are inserted by means of a chute.

The reciprocating action of the rammer causes the tea to pass down through it, the upper edges of the cross-bars being bevelled to facilitate this movement.

In a tea-packeting machine designed by P. C. Larkin the packet is formed about a box, the bottom is closed, and the packet and box are inserted into a mould, where they rest on the top of a plunger.

Tea is then poured into a hopper-shaped receptacle or top to the box, and is pressed down by a plunger actuated by a counterbalanced handle. This plunger is allowed to descend, and

the box is then raised by a lever which operates vertical rods that engage lugs on the hopper, and removed.

The top of the packet is next folded and pressed by turning over a suitable plate and pressing it down through the action of a plunger, and the finished packet is finally removed from the mould by raising the plunger by means of a treadle.

A machine for packeting tea, designed by Harris and Smith, comprises a hopper from which the tea is fed by means of a pair of rotating and reciprocating helices into an adjustable measuring chamber, consisting of a pair of telescoping tubes attached to plates which are kept apart by springs, and are caused to slide along horizontally between two adjustable guides from beneath the mouth of the hopper, to a cavity in a table, by the action of a cam and spring.

The charged chamber in the table is next moved to a point where it will be compressed by a descending plunger, actuated through a crank and levers from a shaft.

A subsequent movement brings the tea over a recess in a lower table which contains the bag, into which it is forced by a plunger operated by a lever. The charge is further compressed by a ram, and is then raised, until the top of its contents are level with the surface of the table, by another plunger operated by a cam.

The top of the packet is finally folded down by blades moved radially by cams and levers, and at a certain point the packet is thrust out of its recess in the table by a plunger, and is received by a platform, from which it is swept by a horizontally moving arm.

The lower table is rotated by ratchet mechanism, actuated by a pin on a wheel and by levers, and the other table is rotated through gearing from the former.

In a machine devised by W. Gilbert the packets are placed in a mould, the sides of which are hinged at the bottom, and are brought together by wedges, on their engaging friction wheels as they move downwards through a hole in the table. The presser is carried by a cross-head, which works in a slot so shaped that the presser may move clear of the path of the mould.

A machine invented by F. A. Eden has an adjustable plunger combined with a movable funnel, which latter is caused to ascend as the former descends, so as to compress the tea into the package in the mould-box. The plunger is operated by a crosshead and rods from crank discs on a shaft, which latter is driven by gearing

from the driving-shaft. The funnel is operated by rods and arms, and an eccentric on the shaft.

An improvement in this machine made by P. Dunlop provides for placing the packet, and the funnel for filling, in a mould beneath the plunger, which compresses the tea while the funnel is being removed. The plunger is operated from a crank-pin on a wheel through rods and levers. A crosshead is provided for raising the funnel, the former being itself raised through suitable linkwork from the above-mentioned crank-pin.

A machine invented by Fielding and White comprises an arrangement by means of which packets containing tea and a funnel are carried in chambers on an intermittently rotating table, and, as each packet comes beneath a press, a plunger descends and compresses the tea. On this plunger rising, lifters also raise the funnel out of the packet, and deposit it in a forked rest.

The table is rotated by ratchet-gearing from a shaft through suitable intermediate gearing.

A cam depresses the plunger through crossheads and rods, and is raised by counterweights. The lifters are raised by cams through a crosshead.

In a machine devised by R. McLeod the tea is weighed and emptied into a hopper, from which it is conveyed by a reciprocating hopper and chute to the packet, which latter is placed at the bottom of a third hopper.

The chute is moved backwards and forwards by means of a cam and spring, its delivery end being forked to clear the stem of the perforated rammer, and being provided with delivery openings. This rammer is worked by a suitable cam.

A machine designed by Kershaw and Kershaw comprises an arrangement of six hinged plates which, when the machine is in its open position, lie flat on the table, the tops of the operating rods being below the level of the table.

A piece of paper to form the packet, which paper is gummed on the right hand edge, is laid on these plates, a square tube having a funnel-shaped end being then placed on this paper, and the above-mentioned rods raised through a treadle, one rod, being longer than the other, coming first into action, and one of the plates being raised first against the side of the square tube, after which it impinges against a projection on the other plate and folds it on to

the top of the square tube. The other rod has meanwhile raised another, or the fourth plate, against the side of the tube, and turned the fifth plate over the top. The first rod now releases the projection on the first of the six plates and permits a spring to raise the latter, a projection on the second rod, through a suitable lever, depressing the sixth plate, and so pressing the gummed part of the paper on to the part that was folded by the first plate.

The end is next folded and the packet filled through the funnel-shaped end of the square tube, which is then removed.

A machine of J. Clyne's comprises means for holding the package adjustably on a vertically-movable table actuated by cams, the fall of the table being arrested and cushioned by springs.

A funnel, with a raised central portion supported by rods, is used for spreading the tea.

Nelson and Slaney's machine comprises a standard having guides for rods, which are connected with crossbars.

To the upper bar of the frame, which latter is suitably counterweighted, is pivoted a rod, with the lower end of which a hand-lever, pivoted to the standard, engages.

The result of this arrangement is, that, if the hand-lever be lowered whilst the above-mentioned rod has a slight amount of play, the frame with the presser attached to the lower cross-bar will move quite vertically.

The case which receives the packets is provided with a bottom adjustably held on a rod actuated by a treadle, thus facilitating the withdrawal of the packages.

A machine designed by Day, Green and Walker comprises a funnel in which the tea is placed, and the end of which is surrounded by a wrapper, and by a block or casing, which is then passed along a guide under a plunger until arrested by a spring stop.

This plunger, which is carried on a counterweighted frame formed of crossheads and connecting rods, is actuated by cams on a shaft connected with the driving-shaft by toothed-gearing. The funnel, when the plunger presses on the tea, is raised by adjustable supporting rods actuated by cams.

As the plunger rises, after the tea is compressed, flanges on the guide prevent the casing from rising also. The package can then be removed, the stop being withdrawn by a cam, and the empty funnel descending below the plunger can be also removed.

In Windust and Hutchison's machine the package to receive the tea is formed on a special mould, having a funnel at the top to facilitate filling, and a guide at the sides to regulate the size of the package.

A special rest receives the mould whilst the package is being formed, and the mould with the package on its end is next placed in a block and the tea is inserted into it, the whole being then moved on to a table filled with sawdust to deaden the noise of the ramming, and a rammer, attached to a pivoted arm worked by a treadle, being operated to pack the tea. The upward movement of the rammer is effected by an indiarubber spring.

Tickle and Leonardt's machine comprises a movable platform, on which is placed a divided box or mould having a number of receptacles to receive the bags to be filled, and which receptacles correspond with a series of spouts projecting from a fixed platform, which latter is located in front of a hopper containing the tea.

The platform and the mould can be raised to the spouts by means of a lever, and are there held in position by a stop, and the platform can be lowered by pressing springs.

In conjunction with the above a sliding drawer is provided, which, in passing under the hopper, receives the tea, and on being drawn forward over the spout strikes against a stop, so as to drive the tea through a grating at the bottom to the spouts and bags.

To effect the adjustment of the tea in the bags the platform can be oscillated by means of cams, and rammers worked by weighted levers are also provided for further pressing it into the bags.

The creasing and folding of the bags is effected by passing the moulds or boxes into a channel on a movable platform, where a forked bar is passed between the open ends of the bags, and front and rear creasers are moved backwards and forwards by an arrangement of levers, thus effecting the two first folds. The other two folds are effected by moving the moulds to the right and left alternately under the creasers, the moulds at this stage being held in position by a lever at each end.

The form of the packet is next made more perfect by raising the movable platform and pressing the packets against the creasers, a honeycombed arrangement at the bottom of each receptacle keeping the bottom of the packets in shape.

Finally the moulds are passed to a skeleton platform and the

bags come against rammers, being thus ejected on to a travelling band which passes them on to be re-wrapped.

A machine invented by T. C. Bell consists of an upper and lower frame, the latter having a number of receptacles or compartments containing the packets, so arranged that they can be opened when the packets are filled.

In another pattern of this machine the tea is poured into the compartments through a sieve, the latter removed, and the top of the compartments levelled off with a scraper, the withdrawal of a plate then allowing the tea to fall into the packets, and the tea, being first all removed from the compartments by shaking, is tightly rammed into the packets. After the packets have been folded and closed, they are pressed simultaneously by a special block.

A machine for packeting tea, invented by F. Wheeler, comprises a turn-table containing four package frames, into which the paper bags are placed, the frames being changeable according to the size of the package required.

On the movement of the turn-table being arrested, one bag is inserted in place into one of the package frames, another is filled under a scales, whilst yet another is folded and gummed; the folding being accomplished by means of lever flaps and slides running in grooves operated upon by a crank, which latter is raised or lowered at the proper time by means of arms worked by projecting pins from the main axle.

The brush for gumming the bag is kept supplied with gum from a suitable reservoir, and is brought down to the top of the bag by means of a cam and lever.

In Ormerod and Higson's machine, the bag to be filled is placed in a mould on a frame, and a funnel is placed in its projecting mouth. The tea having been inserted, a ram operated by a lever and link compresses it. Motion is transferred from the handle to the link lever by oval or elliptical, or eccentric-toothed wheels, so as to cause an increase of pressure to be applied on the rammer towards the close of its descent.

The rammer is raised, and is again lowered after the mouth of the bag has been folded and secured by a gummed label.

In the bottom of the mould is placed a plunger, the rod of which can be geared with a catch on the rammer, and the ascent of which will remove the package from the mould.

The mould and the rammer are so arranged as to be readily removable, so that they can be replaced by others of different sizes.

A machine for measuring and packeting tea, devised by G. Pritchard, has compartments for the bags, open at both ends, and situated in a box, which is mounted on a plate in the lower half of another box, the upper part of which latter carries tapering hoppers having their widest parts below. This box is placed in a recess in the table of the machine, a leaf hinged to the side of the latter being turned down from a vertical position, so as to embrace the ends of the box, and to form an extension of the table. A bar supplies the tea to the hopper, and the above-mentioned plate is so arranged as to be readily removable, so that thicker or thinner plates can be inserted in its stead.

On the removal of the hoppers, the material in them will fall into the bags.

In order to effect the compression of the tea, and the closure of the package or bag, the box containing the latter is removed from the hopper box to another machine, and is passed into a channel against a stop movable by means of a handle. A sliding frame being then pulled forward brings its fingers into spaces between the sides of the ends of the packets, whilst a pin on the frame engages in a hole in the box, so as to connect the latter with a locking bar operated by a lever, and capable of a slight to-and-fro, or reciprocating, movement in an upright on the frame, the connection of the box with the locking bar pushing the stop out of the path of the box. A bar mounted on slides, working on other slides, carrying a plunger bar, has a pair of jointed flaps so weighted as to normally hang obliquely pointing towards one another. On two levers connected by a shaft being operated, these bars will be lowered together, the flaps on the latter entering the mouths of the bags, stops fixed on the upright of the machine, and working in slots in the slides of the above-mentioned bars, finally arresting the movement of the latter.

The plungers provided on the plunger-bar enter between the flaps, thus opening and expanding the mouths of the bags whilst compressing the material. Two levers connected by rods, and each having a slot and working on a pin fixed in an upright position, are oscillated by hand to a horizontal position. During

their descent they act upon the short ends of levers, each of which has a slot working on a pin, and bring the levers to a horizontal position. Pins on pivoted face-plates, so weighted as to cause them to assume the proper position, next enter into curved grooves in the levers, and pieces, on bars carried between the pairs of levers, act to partially close the sides of the bags. The first of the above-mentioned levers being drawn towards the operator, the slotted levers through the action of the face-plates will be moved in a reverse direction, so that the pieces will then completely close the two sides of the bag.

The frame carrying the fingers has also attached to it the bar of a comb-plate, which works in guides on the bar carrying the fingers. The frame-operating lever is moved to the right with the box, by which action the third side of each bag is closed by the fingers, whilst a catch on the mould engages with a pawl on the comb-plate bar. By reversing the frame-operating lever the mould can be moved back with the comb, the teeth of the latter remaining upon the side last closed on each bag, and the fourth side being closed by passing beneath the fingers.

Whilst the fourth side is being closed, a pin on the box containing the bag disengages the before-mentioned pawl, and a crosspiece on the comb-bar presses upon a pivoted lever, which then bears against the other end of the box, whose movement finally pushes back the lever, which returns the comb to its normal position.

To level the folds the plungers are lowered, and as the frame moves back a rod thereon strikes against an inclined surface on the bed-plate, and returns the locking-pin to its original position.

The above-mentioned box is then removed, and is advanced, between guides on a table, against blocks fixed on a support therein. One of these blocks enters each compartment in the box, and forces the package into a compartment in a tray placed at the back of the box. These trays are located on a platform, from which they are carried by a suitably supported endless band, having pieces between which the trays are placed, the band being moved by pushing the trays.

The packets are removed directly the trays arrive opposite a re-wrapping table, and the empty trays fall through an opening in

the table carrying the band, and are caught by the pieces on the band and returned.

In the Cleveland Paper Box Machine Company's machine the material is placed in a hopper drawer arranged to slide in a suitable frame.

The measures are fitted with screw-adjusting or regulating plates, and are formed in a frame removable from the apparatus through a suitable door, and upper and lower cut-off plates, having central openings, and operated by levers, are provided. When the upper cut-off plate is drawn out the measures will be filled, the air escaping from them during the operation through passages into an upper chamber, and thence through side-openings into the atmosphere.

The upper plate is then pushed in, and the lower plate drawn out, upon which the tea will pass or fall through suitable chutes, arranged in a removable frame, into packages placed on a tray with dropping doors at each side, which can be raised into position by means of a platform on a standard operated by a foot lever, and may then be supported by stays which, when pushed in by means of rods, rest on loose bearings carried by agitating wheels driven by a pulley. When the stays are drawn out and the platform lowered, the trays will rest on the loose bearings, and may again be shaken by means of the agitating wheels.

Two machines invented by J. Joyce comprise, the first a circular table carrying a number of moulds, rotated, by an intermittent feed motion, upon a bed-plate, the moulds being brought in succession beneath a vertical rammer carried by a crosshead. Funnels of suitable shape are provided, around which an attendant folds the wrappers, which are then placed in the moulds, and into these the tea is weighed or measured.

After receiving the pressure of the rammer the funnels are automatically removed, the wrappers folded over by an attendant, and the packet ejected, as it passes over a hole in the bed plate, by a rod which rises there-through. Suitable cams and gearing on a driving-shaft, located beneath the bed-plate of the machine, actuate the various parts.

The second machine has a ring carrying moulds in which funnels, round which wrappers have been folded, are inserted as before, and filled with tea.

This ring is rotated by a pawl on a lever worked by a rack and pinion, the ring having been previously unlocked by another lever, for a distance equal to the space between two stops, for each revolution of a counter shaft actuated from a main shaft, thus bringing the mould beneath a crosshead having two rods actuated by cams balanced by weights, by which the crosshead, the stroke of which can be increased by a lever when necessary, is lowered on its guides so that its adjustable rammer will enter the funnel, compress the tea, and again rise. The funnel is next lifted from the mould by two rods raised by a cam, or by a stud on a spur wheel, and is carried to its original position by a fork on a lever, worked by a rack and pinion. On one rod is a spring which unlocks a spring-bolt, and releases the rammer when necessary.

The ring then moves through a second interval, and the package is folded, the third movement bringing it over an aperture in the bed-plate, through which a rod, actuated by a stud on the above-mentioned spur wheel, or by a cam, passes, and removes the package. At each position of rest the rotating ring is locked by a pin actuated from the counter shaft.

This second movement brings the mould between folders, a slide pushed forward by a spring folding one side of the packet. A gut, worked through a lever by a cam, actuates another lever, which engages a latch, and through the operation of a disc opens the above-mentioned arms or slides, which throw out the packet corners while they recede. A plate is then advanced in a similar manner and levels off the top of the packet, whilst two levers, actuated bv a rack and pinion, fold the corners.

A machine devised by Forbes and Grover would be especially suitable for wrapping blocks of compressed tea. In this machine the blocks to be wrapped are fed by a conveyer into a hopper. A reciprocating slide brings wrapping boxes alternately under the feed-hopper, and at the same time the paper is drawn across so as to lie upon the spread-out leaves of the wrapping box. As the block is deposited upon the paper the leaves of the folding box are raised up and the paper folded. The box then moves on, and suitable mechanism completes the locked fold, tucks the paper into the channel, folds over the remaining tabs, and discharges the wrapped block from the machine.

CHAPTER XVII.

TABLES AND MEMORANDA.

Useful Information relating to Blackman Fans—Notes on Air—Weight of Vapour in Saturated Air—Discharge of Water over a Weir—Velocity of Water through Pipes—Table of Results of Operations of Hydraulic Ram—Pressure of Water—Speeds of Woodworking Machines—Speeds of Cutting Tools for Metals—Speeds of Milling Cutters—Pitch of Cutter Teeth—Lubrication—Bearings—Lime in Tea Soils—Values of Various Manures—Percentages of Ash in various Teas—Composition of Teas—Remedies for Tea Blight—Tea Analyses—Behaviour of Theine and Theobromine with Reagents—Properties of Theine or Caffeine—Adulteration of Tea with Foreign Leaves—Indian Weights and Measures and other Tables—Particulars required to estimate for an Aërial Tramway—Estimate for a Light Line of Aërial Tramway—Table of Working Strength of Ropes in Tons

Useful Information relating to Blackman Fans.

TO ASCERTAIN VOLUME OF AIR MOVED, AND SPEED REQUIRED. —A simple and practically correct rule for finding the volume of air moved by a Blackman is:—Diameter in feet × area in square feet × revolutions per minute = volume of air moved in cubic feet per minute. Take a 48-inch Blackman, the area of which is 12·5 square feet; then 4 × 12·5 × 500 revolutions = 25,000 cubic feet moved in a minute. Conversely, to ascertain the speed of a 48-inch Blackman for removing 25,000 cubic feet, divide that number by 12·5 = 2,000 feet, *i.e.*, the velocity of the discharged current; divide this again by 4, and the quotient 500 = revolutions per minute required. When more power is required to drive than should be the case, it will generally be found that the supply (or inlet area) is too small, or not free; any excess of power consumed being due to the resistance met with by the air. Do not drive faster than is necessary for the purpose in view. According to a well-known law, it is much more economical of power to move any given quantity of air at a moderate speed, than to move the

same quickly. Suit your speed to your work and the weather, remembering that excessive speed is wasteful.

The speed of a fan is also proportioned to its diameter. A small fan can be run at a very much higher speed than a large fan. The theory, which governs the practice, is this:—The speed of the rim of fans of all sizes should be the same. So the calculation of speed for size can be found by arithmetic, when this theory is used as a basis. Thus a 24-inch fan may be run at about double the speed of a 48-inch fan, and the speed of the air current in both cases is about the same, but from the difference in the size of their areas, the 48-inch delivers about four times as much air as the 24-inch, or as their relative areas in square feet. In practice there are slight modifications, which, however, need not here be taken into account.

Be careful to bear in mind that the power required to drive any fan at twice the speed is more than four times that taken at the lower speed, and inversely in proportion. In other words, if you double the speed, you expend four times the power to obtain only double the quantity of air.

In cold weather run the fans slowly, so as not to exhaust the available supply of heat too rapidly, if it is deficient. If there is not then sufficient heat for the whole loft, stop the fans in one portion, and close the inlet opposite these, and only use the other fans dead slow, if necessary. With sufficient heat, it does not matter how wet the leaf is. If, even then, heat is deficient, light up, for the sake of the wither, any dryers left not already lighted.

Fixing True.—It is most important that the spindles of the fans and any counter shaft, such as is sometimes necessary, should be set exactly parallel to the main shafting.

Belt Slipping.—Be extremely careful that no "slip" takes place in the running of any belt. The belts should be kept properly tightened up. If any slip occurs, all the fans on the offside of the slip run slower than calculated for, and a great deal of power is wasted.

Belting.—Avoid hard belts. These will not grip properly, and will entail loss of speed and loss of power. Select belts for their lightness, softness, and pliability.

Cotton belting is good if new. It gets hard if kept in stock, unused, over twelve months. The number of plies should vary

according to the position, in its set, of the fan to be driven, if economy is to be combined with efficiency.

HALF-CROSSED BELTS.—As these are often used, and not always understood without previous experience, it may be useful to point out the simple condition on which their satisfactory running depends.

Considering each pulley as having no breadth, but consisting of a thin flat disc only, the point where the belt leaves either pulley must be in the same plane as the other pulley.

DRIVING BY ROPE.—As a rule, the strain on any rope driving a Blackman fan is very slight; it is the bending of the rope much and often that causes wear. To be durable, therefore, a rope should be a long one and of small diameter, and the smallest pulley used should be not less than twenty times as much in diameter as the rope.

BROKEN FLANGES.—Should a flange or shroud on a pulley be broken by accident, it may be pointed out that only one flange is necessary, and that two are only put on because it cannot always be foreseen upon which side of the pulley the flange should be. Hence, when this is determined, fit on the pulley, with the remaining flange to that side. Moreover, if the pulley on fan spindle is not near the blades, no flange at all is necessary. A rounded or convex-faced pulley is a better means of keeping the belt in its true position than any flange can be, as the belt rises to the greatest diameter, viz., the centre.

GUIDE PULLEYS.—To obviate difficulty in conveying power to the best positions in a building, in which to place a fan, guide pulleys for either belt or rope driving may be used. These can be obtained fitted with adjustable brackets, lubricators, etc., complete and suitable for almost any case.

FORMULÆ: (1) TO FIND THE DIAMETER OF THE DRIVING PULLEY.—Multiply the desired number of fan revolutions by diameter in inches of the fan pulley, and divide the result by the speed of the driving-shaft. Example: say you have a 48-inch fan with an 8-inch pulley and a shaft running at 100 revolutions per minute, and the required speed of fan to be 500 revolutions; then 500 × 8 inches = 4,000 ÷ 100 = 40 inches, size of pulley required.

(2) TO FIND SPEED OF FAN.—Multiply the diameter of driving

pulley in inches by the speed of the shaft, and divide the result by the diameter of the fan pulley in inches. Example: 40 inches × 100 ÷ 8 = 500 = speed of fan per minute.

LUBRICATION.—Frequent attention should be given to lubrication during the first day or two, afterwards a half-turn of each lubricator cap should be given once or twice a day, as experience may prove to be necessary. The half-turn forces the lubricant into the bearing.

Years of experience have convinced the makers that no other lubricant answers so well as Stauffer's for use with their fans. Oil is apt to fly off and make a mess, and is also otherwise objectionable.

CHEAP WINDOWS.—Windows sometimes become necessary for the admission of light, after the erection of a ceiling cloth, in positions where they were formerly not required, and these, or others, may be economically filled with well-oiled canvas tacked in a wooden frame. These will admit about as much light as ground glass. Boiled linseed oil will be found the best for the purpose.

NOTES ON AIR.

One Atmosphere

= 14·7 lb. per square inch.
= 29·922 inches of mercury } at 62° Fahr.
= 33·947 feet of water }
13 cubic feet of air weigh 1 lb.
1 lb. of water = 7000 grains.

Moist air is lighter than dry air at the same temperature.

WEIGHT IN GRAINS OF VAPOUR IN A CUBIC FOOT OF SATURATED AIR, *i.e.*, AT THE TEMPERATURE OF THE DEW, OR CONDENSATION POINT. BAROMETER 29 INCHES.

Deg.	Grs.	Deg.	Grs.	Deg.	Grs.	Deg.	Grs.	Deg.	Grs.	Deg.	Grs.
71	8·24	76	9·66	81	11·28	86	13·13	91	15·24	96	17·62
72	8·51	77	9·96	82	11·63	87	13·53	92	15·69	97	18·14
73	8·79	78	10·27	83	11·99	88	13·93	93	16·15	98	18·67
74	9·07	79	10·60	84	12·36	89	14·36	94	16·63	99	19·22
75	9·36	80	10·94	85	12·74	90	14·80	95	17·12	100	19·77

When the Barometer is at 30 inches add about $\frac{1}{30}$ to these weights.
The Degrees are Fahrenheit.

VELOCITY OF WATER THROUGH PIPES (*Günther*).

of Pipe in Inches.	N.B.—"Loss of fall" is for every 100 ft. of Piping.	VELOCITY OF WATER THROUGH PIPES IN FEET PER SECOND.								
		2	2·5	3	3·5	4	4·5	5	5·5	6
3	Cubic ft per min.	5 9	7·3	8 8	10·3	11·8	—	—	—	—
	Loss of fall in feet.	1 1	1·7	2·1	2·9	3·7				
4	Cubic ft per min	10·5	13	15·7	18·3	21	—	—	—	—
	Loss of fall in feet.	0 63	1·0	1·4	1 9	2·5				
5	Cubic ft per min.	16 4	20·4	24·5	28 6	32 7	—	—	—	—
	Loss of fall in feet.	0·47	0·73	1 05	1·4	1 9				
6	Cubic ft. per min	23 6	29 3	35 2	41 2	47	53	—	—	—
	Loss of fall in feet.	0 37	0 57	0 82	1 1	1 5	[illegible] 8			
7	Cubic ft. per min.	32	40	48	56	64	72	—	—	—
	Loss of fall in feet.	0 30	0·47	0·67	0·92	1 2	1·5			
8	Cubic ft. per min.	42	52	63	73	84	94	—	—	—
	Loss of fall in feet	0 25	0·39	0·56	0 77	1 0	1 3			
9	Cubic ft. per min.	53	66	79	93	106	119	133	—	—
	Loss of fall in feet	0 21	0 33	0 48	0 66	0 86	1 1	1·3		
10	Cubic ft. per min.	65	82	98	115	131	147	164	—	—
	Loss of fall in feet.	0·19	0 29	0 42	0 57	0 75	0 95	1 2		
12	Cubic ft. per min.	94	117	141	165	188	212	235	—	—
	Loss of fall in feet.	0·15	0 23	0·33	0 45	0·59	0 75	0·9		
14	Cubic ft. per min	128	160	192	224	257	288	320	352	—
	Loss of fall in feet	0·12	0 19	0 27	0 37	0 49	0 61	0 76	0·92	
15	Cubic ft. per min	148	184	220	258	295	331	368	405	—
	Loss of fall in feet.	0·11	0·17	0·25	0 34	0 44	0·56	0·7	0·84	
18	Cubic ft. per min.	212	264	317	372	425	475	530	580	—
	Loss of fall in feet	0·09	0 14	0·20	0 27	0 35	0 44	0·55	0·67	
21	Cubic ft. per min.	288	360	430	505	575	650	720	790	—
	Loss of fall in feet.	0·07	0·11	0·16	0·22	0·29	0·37	0·45	0·55	
24	Cubic ft. per min.	377	470	565	660	755	845	940	1030	1130
	Loss of fall in feet.	0·06	0·10	0·14	0·19	0·25	0 31	0 38	0·46	0·55
27	Cubic ft. per min.	478	595	715	835	955	1070	1190	1310	1430
	Loss of fall in feet.	0·05	0·08	0·12	0·16	0·21	0 27	0·33	0·40	0·48
30	Cubic ft. per min.	590	730	880	1030	1180	1320	1470	1610	1760
	Loss of fall in feet.	0·045	0·073	0 10	0 14	0 19	0·24	0 29	0·34	0·42
33	Cubic ft. per min.	710	890	1070	1250	1420	1600	1780	1950	2140
	Loss of fall in feet.	0 042	0·065	0 093	0·13	0 17	0 21	0 26	0 31	0·37
36	Cubic ft. per min.	850	1000	1270	1480	1700	1900	2120	2330	2540
	Loss of fall in feet	0·037	0·058	0 084	0·12	0·15	0·19	0·23	0·28	0·34
39	Cubic ft. per min.	994	1242	1491	1739	1988	2230	2485	2701	2982
	Loss of fall in feet.	0·035	0 055	0·078	0·107	0·14	0·18	0·22	0 26	0·32
42	Cubic ft. per min.	1150	1440	1730	2020	2300	2590	2880	3170	3450
	Loss of fall in feet.	0 031	0·048	0·070	0·095	0·12	0·16	0 19	0·23	0·28
45	Cubic ft. per min.	1323	1654	1985	2316	2647	2977	3308	3639	3970
	Loss of fall in feet.	0·029	0·046	0 066	0·090	0·118	0·15	0·18	0·22	0·26
48	Cubic ft. per min.	1500	1880	2250	2630	3000	3380	3750	4130	4500
	Loss of fall in feet.	0·026	0·040	0·058	0·078	0·10	0·13	0 16	0·19	0·23
51	Cubic ft. per min.	1680	2100	2520	2940	3360	3780	4200	4620	5040
	Loss of fall in feet.	0·025	0·038	0·056	0·075	0·098	0·126	0·153	0·185	0·22
54	Cubic ft. per min.	1906	2382	2859	3335	3811	4288	4765	5241	5718
	Loss of fall in feet.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0·18	0·21

PRESSURE OF WATER (*Worthington*).

The pressure of water in pounds per square inch for every foot in height to 270 feet. By this Table, from the pounds pressure per square inch the feet head is readily obtained, and *vice versâ*.

Feet Head.	Pressure per sq. inch.	Feet Head.	Pressure per sq. inch.	Feet Head.	Pressure per sq. inch.	Feet Head.	Pressure per sq. inch.	Feet Head.	Pressure per sq. inch.	Feet Head.	Pressure per sq. inch.
1	0.43	46	19.92	91	39.42	136	58.91	181	78.40	226	97.90
2	0.86	47	20.35	92	39.85	137	59.34	182	78.84	227	98.33
3	1.30	48	20.79	93	40.28	138	59.77	183	79.27	228	98.76
4	1.73	49	21.22	94	40.72	139	60.21	184	79.70	229	99.20
5	2.16	50	21.65	95	41.15	140	60.64	185	80.14	230	99.63
6	2.59	51	22.09	96	41.58	141	61.07	186	80.57	231	100.06
7	3.03	52	22.52	97	42.01	142	61.51	187	81.00	232	100.49
8	3.46	53	22.95	98	42.45	143	61.94	188	81.43	233	100.93
9	3.89	54	23.39	99	42.88	144	62.37	189	81.87	234	101.36
10	4.33	55	23.82	100	43.31	145	62.81	190	82.30	235	101.79
11	4.76	56	24.26	101	43.75	146	63.24	191	82.73	236	102.23
12	5.20	57	24.69	102	44.18	147	63.67	192	83.17	237	102.66
13	5.63	58	25.12	103	44.61	148	64.10	193	83.60	238	103.09
14	6.06	59	25.55	104	45.05	149	64.54	194	84.03	239	103.53
15	6.49	60	25.99	105	45.48	150	64.97	195	84.47	240	103.96
16	6.93	61	26.42	106	45.91	151	65.49	196	84.90	241	104.39
17	7.36	62	26.85	107	46.34	152	65.84	197	85.33	242	104.83
18	7.79	63	27.29	108	46.78	153	66.27	198	85.76	243	105.26
19	8.22	64	27.72	109	47.21	154	66.70	199	86.20	244	105.69
20	8.66	65	28.15	110	47.64	155	67.14	200	86.63	245	106.13
21	9.09	66	28.58	111	48.08	156	67.57	201	87.07	246	106.56
22	9.53	67	29.02	112	48.51	157	68.00	202	87.50	247	106.99
23	9.96	68	29.45	113	48.94	158	68.43	203	87.93	248	107.43
24	10.39	69	29.88	114	49.38	159	68.87	204	88.36	249	107.86
25	10.82	70	30.32	115	49.81	160	69.31	205	88.80	250	108.29
26	11.26	71	30.75	116	50.24	161	69.74	206	89.23	251	108.73
27	11.69	72	31.18	117	50.68	162	70.17	207	89.66	252	109.16
28	12.12	73	31.62	118	51.11	163	70.61	208	90.10	253	109.59
29	12.55	74	32.05	119	51.54	164	71.04	209	90.53	254	110.03
30	12.99	75	32.48	120	51.98	165	71.47	210	90.96	255	110.46
31	13.42	76	32.92	121	52.41	166	71.91	211	91.39	256	110.89
32	13.86	77	33.35	122	52.84	167	72.34	212	91.83	257	111.32
33	14.29	78	33.78	123	53.28	168	72.77	213	92.26	258	111.76
34	14.72	79	34.21	124	53.71	169	73.20	214	92.69	259	112.19
35	15.16	80	34.65	125	54.15	170	73.64	215	93.13	260	112.62
36	15.59	81	35.08	126	54.58	171	74.07	216	93.56	261	113.06
37	16.02	82	35.52	127	55.01	172	74.50	217	93.99	262	113.49
38	16.45	83	35.95	128	55.44	173	74.94	218	94.43	263	113.92
39	16.89	84	36.39	129	55.88	174	75.37	219	94.86	264	114.36
40	17.32	85	36.82	130	56.31	175	75.80	220	95.30	265	114.79
41	17.75	86	37.25	131	56.74	176	76.23	221	95.73	266	115.22
42	18.19	87	37.68	132	57.18	177	76.67	222	96.16	267	115.66
43	18.62	88	38.12	133	57.61	178	77.10	223	96.60	268	116.09
44	19.05	89	38.55	134	58.04	179	77.53	224	97.03	269	116.52
45	19.49	90	39.98	135	58.48	180	77.97	225	97.46	270	116.96

Discharge of Water over a Weir (*Günther.*)

Depth (*h*) on Weir in inches.	0	⅛	¼	⅜	½	⅝	¾	⅞
1	·40	·43	·55	·65	·74	·83	·93	1·03
2	1·14	1·19	1·36	1·47	1·59	1·71	1·83	1·96
3	2·09	2·16	2·36	2·50	2·63	2·78	2·92	3·07
4	3·22	3·29	3·52	3·68	3·83	3·99	4·16	4·32
5	4·50	4·58	4·84	5·01	5·18	5·36	5·54	5·72
6	5·90	6·00	6·28	6·47	6·65	6·85	7·05	7·25
7	7·44	7·54	7·84	8·05	8·25	8·45	8·66	8·86
8	9·10	9·20	9·52	9·74	9·96	10·18	10·40	10·62
9	10·86	10·97	11·31	11·54	11·77	12·00	12·23	12·47
10	12·71	12·83	13·19	13·43	13·67	13·93	14·16	14·42
11	14·67	14·79	15·18	15·43	15·67	15·96	16·20	16·46
12	16·73	16·86	17·26	17·52	17·78	18·05	18·32	18·58
13	18·87	19·01	19·42	19·69	19·97	20·24	20·52	20·80
14	21·09	21·23	21·65	21·94	22·22	22·51	22·79	23·08
15	23·38	23·53	23·97	24·26	24·56	24·86	25·16	25·46
16	25·76	25·91	26·36	26·66	26·97	27·27	27·58	27·89
17	28·20	28·35	28·82	29·14	29·45	29·76	30·08	30·39
18	30·70	30·86	31·34	31·66	31·98	32·31	32·63	32·96

Table of Results of Operations of Hydraulic Rams (*Kempe*).

Number of Strokes.	Height of Fall.	Height of Elevation.	Water Expended.	Water Raised.	Useful Effect.
Min.	Feet.	Feet.	Cubic Feet.	Cubic Feet.	
66	10·06	26·3	1·71	·543	·9
50	9·93	38·6	1·93	·421	·85
36	6·05	38·6	1·43	·169	·75
31	5·06	38·6	1·29	·113	·67
15	3·22	38·6	1·98	·058	·35
10	1·97	38·6	1·58	·014	18
—	22·8	196·8	·38	·029	·67

Speeds of Wood-working Machines.

Circular saws for ripping soft wood 9,000 feet per minute at periphery.
,, ,, ,, hard wood 7,000 ,, ,, ,,
,, for cross-cutting soft wood 10,000 ,, ,, ,,
,, ,, ,, hard wood 8,000 ,, ,, ,,
Band saws for sawing soft wood 5,000 feet traverse of blade per minute.
,, ,, ,, hard wood 3,500 ,, ,, ,,
Planing machines 6,000 feet per minute at cutting edge.
,, ,, depth of each cut $\frac{1}{16}$th of an inch.

SPEEDS OF CUTTING TOOLS FOR METALS (*Molesworth*).

Speeds for cast iron generally, 150 to 190 inches per minute, boring 80 inches per minute.

Speeds for wrought iron, about 260 to 280 inches per minute.

For yellow brass, about 300 inches per minute.

Speed of planers, about 15 feet per minute.

Speed of shapers, about 12 feet per minute.

For drilling, tapping, or boring, the speed of the circumference of the tool should be from 80 to 120 inches per minute in cast iron, and from 140 to 160 in wrought iron.

SPEEDS OF MILLING CUTTERS 6 INCHES DIAMETER AND UPWARDS (*Kempe*).

	Speed in feet per minute.	Depth of cut in inches
Steel	36	$\frac{1}{2}$
Iron	48	1
Cast-iron	60	$1\frac{1}{4}$
Brass	120	$2\frac{1}{4}$

PITCH OF CUTTER TEETH.

For cutters from 4 to 15 inches in diameter: Pitch of teeth in inches $= \sqrt{(\text{diameter in inches} \times 8)} \times \cdot 0625$

LUBRICATION.

A few words upon this important subject will not be out of place. For more extended information, however, the author begs to refer the reader desirous of going more fully into the matter to his previous work upon "Bearings and Lubrication," * wherein it will be found specifically dealt with.

Shortly, lubrication is intended to diminish, as far as possible, the friction that takes place between rubbing surfaces, and thereby to prevent those surfaces from heating, and to reduce to a minimum the wear and tear of the parts.

This friction is the result of one body rolling or sliding upon another body, the amount of friction thus engendered being governed by the pressure to which these bodies are subjected, conjointly with the nature of the surfaces that are in contact, but the greater or lesser extent of those surfaces being immaterial theoretically so far as the amount of the friction is concerned.

Heating of the rubbing surfaces of machinery is produced by the interlocking of the unavoidable inequalities of these surfaces,

* "Bearings and Lubrication, a Handbook for Every User of Machinery," by the author of this work (London: William Rider & Sons, Limited).

as they pass over each other, and the constant vibration produced thereby.

It is practically an impossibility to produce two bearing surfaces perfectly pure or true, and were this even not the case, such surfaces would be undesirable, as pressure would cause them to unite in one piece.

The friction between two surfaces in rubbing contact can only be reduced by filling up the above-mentioned inequalities with lubricants, and thereby preventing, to a greater or lesser extent, the vibration caused by the violent interlocking of these inequalities.

The aim of perfect lubrication should be to cause the journal to be completely oil-borne, and to approximate the friction as nearly as possible to that of liquids, or rather to that of solids upon liquids.

Two kinds of lubricants are employed, viz., liquid lubricants for the reduction of friction, and greases of a solid or semi-solid consistency for preventing the over-heating of the parts by melting and running into the bearing as soon as the temperature begins to rise abnormally. These latter classes of lubricants are now, however, much used in special lubricators, by which they are forced into the bearing, for ordinary purposes of lubrication, and, as has been already mentioned, this type of lubricant is the one best adapted for use with fans.

Liquid lubricants comprise such fluids as water, and vegetable, animal, and mineral oils.

Solid and semi-solid lubricants comprise greases, tallows, fresh lard, soap, palm oil, powdered plumbago, graphite, talc, &c., and numerous artificial mixtures consisting of fats, resins, water, soda, and many other compounds.

The following are the principal features to be looked for in a good lubricant:—

It should reduce the friction to a minimum, be perfectly neutral, and uniform in composition.

It should be absolutely free from any inorganic matter or grit, and from any gumming properties or disagreeable smell.

It should not become appreciably altered by exposure to the air.

It should be capable of standing a high temperature (612° Fahr.) without any loss or decomposition, and a low temperature (18° Fahr.) without solidifying or depositing solid

matters. The latter quality, however, being one of minor importance, as only obviating the inconvenience that might otherwise result from the oil congealing in the lubricators and oil cans, or other vessels, in cold climates.

Finally it should be entirely free from acids, which have a highly corrosive action on bearings, and on other parts of machinery, and it should not stain bright work, even when left upon it for a considerable length of time.

The adaptability of a lubricant to the requirements of light or heavy bearings is an important question. For bearings subjected to light pressures, oils of a fluid nature are most suitable, whilst for bearings subjected to heavy pressures lubricants of greater consistency are the best. Under certain conditions solid or semi-solid lubricants are to be preferred.

Oils for use in steam-engine cylinders, and on slide valves, should not be liable to oxidise, and should be absolutely free from the objectionable quality of developing acids which corrode metals, and of forming in the cylinders, steam chests, condensers, and boilers, deposits of a mucilaginous substance, which interfere to no small extent with efficient working. Cylinder oils, moreover, are subjected to high temperatures, and must possess more body or consistency than oils only intended for the ordinary purposes of lubrication. Owing to their stability, mineral oils are peculiarly suitable for this purpose, but they should be free from light oil or naphtha (of which the flash point is an indication), which would be injurious to packings, especially of indiarubber; they should not, moreover, have a boiling point below 600° Fahr., nor give off smoke under 400° Fahr., and their firing or flashing point should not be under 550° Fahr. They should have at least an equal body to castor-oil, or five or six times that of colza oil.

A mixture of lard oil, 2 parts, good quality mineral oil, 3 parts, and finely-powdered graphite, ⅛ part, forms a good cylinder lubricant.

For the lubrication of extensive surfaces, or where there is a high velocity and little pressure, mineral oils are preferable. For ordinary use mineral oils should have a specific gravity of 90 at a temperature of 60° Fahr., and should not give off inflammable vapours at a temperature under 350° Fahr.

For bearings subjected to a heavy pressure, and especially for

those of new machinery, and in hot climates, castor-oil is the most suitable.

For railway purposes the best axle greases should contain at least 35 per cent. of a mixture of tallow and palm oil.

BEARINGS.*

Each degree of heat that is produced in a bearing by friction, is so much power completely lost and thrown away. So many degrees of heat, therefore, produced in a machine bearing, above that of the atmosphere, are equivalent to as many degrees extracted from under the boiler; the heat, instead of performing useful work, causing only so much additional wear and tear to the machinery, and extra waste.

In order to insure a bearing running cool, the following conditions must be complied with:—The journal and bearing must be made of proper materials. The wearing surfaces must be perfectly smooth, of sufficient areas, and have an uniform bearing. They must be provided with such oil ways as will evenly distribute the lubricant to every portion thereof. The supply of lubricant must be constant, regular, and sufficient in quantity. All dust, dirt, and other foreign bodies must be rigorously excluded.

LIME IN TEA SOILS (*Bamber*).

	Assam.	Cachar.	Kangra.	Darjeeling.	Dooars.	Chota-Naypar.
Sample 1	Trace	Trace	·38	·48	·14	·01
„ 2	„	„	·39	·15*	·30	..
„ 3	„	„	·06	..	1·50†	..
„ 4	„	„	·17	..	..	..
„ 5	„	·19	·12	..	..	..
„ 6	·10	·11	·58	..	..	..
„ 7	·15	·12	..	..	..	..
„ 8	·31	·05	..	..	..	..
Average	·07	·06	·29	·32	22	·01

* Average of 6 samples.
† Exceptional percentage from soil at the foot of some limestone hills.

* For further information on this subject, see "Bearings and Lubrication," by the same author.

VALUES OF VARIOUS MANURES (*Bamber*).

Manure.	Guaranteed percentage.		Value per unit.	Price per ton.
Ammonium Sulphate	24	per cent. Ammonia	£0 10 6	£12 15 0
Sodium Nitrate	19	" "	0 9 6	9 0 0
Castor Cake Dust	5·5	" "	0 12 6	3 10 0
Rape	4·5	" "	0 17 0	4 0 0
Horn Dust	14·00	" "	0 10 6	7 7 0
Shoddy and Ground Leather	12·00	" "	0 6 0	3 10 0
Dried Blood	15·00	" "	0 10 9	8 0 0
Potassium Chloride, 80 per cent.	50 00	" Potash	0 3 3	8 0 0
Potassium Sulphate, 50 per cent	27 00	" "	0 3 3	4 10 0
Kainit	12·00	" "	0 3 0	1 13 0
Potassium Nitrate, 85 per cent.	40 00	" "	0 4 0	16 10 0
	14 00	" Ammonia	0 12 6	
Ground Charlestown Phosphate	54·00	" Phosphate	0 0 10	2 5 0
Basic Slag Meal	40·00	" "	0 0 10	1 12 6

PERCENTAGE OF ASH IN VARIOUS TEAS (*Warrington*).

	Grains of Ash.
Java Gunpowder	5·0
Gunpowder during the East India Company's Charter.	6·5
Kemaon Hyson	5·0
Assam Hyson	6·0
Lie Gunpowder, No 1	45·5
Scented Caper	5·5
Lie Flower Caper	37·5
Mixtures containing these Lie Teas, No. 1	22·5
Ditto ditto No. 2	11·0

COMPOSITION OF TEA (*Buckmaster*).

Water			5·0
Flesh-formers	Theine	3·00	18·00
	Casein	15 00	
Heat-formers	Aromatic oil	0 75	25 75
	Sugar	3·00	
	Gum	18·00	
	Fat	4·00	
Tannic acid			26·25
Woody fibre			20 00
Mineral matter			5·00
			100·00

CONSTITUENTS OF TEA.

It is usual to designate the constituents of tea as flesh-formers and heat-formers, but, in point of fact, it is almost beyond a doubt that tea has no claim whatever to the possession of any such value, as it is practically certain that it is not digested.

The use of tea, then, really depends upon the undoubtedly tasteful, refreshingly stimulating beverage which it produces, and not upon the possession of any food-power.

The stimulating property of tea is mainly due to its active principle theine or methyl-theobromine ($C_8H_{10}N_4O_2+H_2O$).

The amount of this alkaloid found in tea by different analysers varies considerably; the quantity given by Sir Henry E. Roscoe is about 2 per cent.

Remedies for Tea Blight.

Take a quantity of common starch, dissolve to the consistency usual when required for getting up linen, choose a fine bright morning, and before the sun gets hot, smear the starch well over the plants affected. In some fifteen minutes the starch sets, and in an hour or two it all peels off, taking with it the dead insects along with their eggs and progeny, and leaving the plants quite clean.—(*B. Ribbentrop, Inspector-General of Indian Forests*).

Powdered flowers of sulphur dusted upon the leaves of the affected bush, or syringing with a solution of lime and sulphur is stated to have been tried with considerable success, and syringing with a solution of sulphate of copper has likewise been used.

According to Mr. Christison, sulphur is a very effectual remedy for "red spider," and it also acts as an excellent manure for many descriptions of soils.

Other insecticides proposed to be used for tea plants comprise: Sulphide of carbon, petroleum (crude), emulsion of kerosene, sulpho-carbonate of potash, solution of whale soap, extract of adhotoda vasica, applications of a compound known as London purple, vaporization with carbonic acid and lime, inoculation with carbonic acid, &c., &c.

It has also been recommended to introduce into the ground in which the seeds are to be sown, the plants are to be set, or at the roots of the tea shrubs, a mixture of 20 to 25 parts of natural bitumen in a fine state of division, with 80 to 75 parts of dry earth, powdered clay, or powdered chalk.

Tea Analyses.

Average of Indian, Ceylon, and common Chinese and Japanese Teas (*Crole*).

	No. 1.	No. 2.	No. .
Ash	6·62	6 5	6·35
Extracts / Soluble Salts	39·80 to 40·35	38·4 to 43·02	26·20
Theine	1·88 to 3·24	1·64 to 2·18	1·08 to 3·46

Chinese and Japanese Teas (*Elder*).

Ash	5·7
Extracts / Soluble Salts	30·00
Theine	2·00

Japanese Teas (*Kinch*).

	No. 1.	No. 2.	No. 3.
Ash	6·53	6·10	6·50
Extracts / Soluble Salts	43·26	52·55	36·50
Tannin	12·50	12·10	13·9
Theine	5·79	6·33	3·18

Average of Six Ceylon Teas (*Dunn*)

Ash	4·82
Extracts	42·2
Soluble Salts	3·05
Theine	1·74

Average of Fifteen Indian Teas (*Newberry*).

Ash	5·34
Extracts	39·42
Soluble Salts	3·16
Theine	1·94

Average of Fifteen Foochow Congous (*Newberry*).

Ash	5·20
Extracts	29·26
Soluble Salts	2·88
Theine	1·84

Approximate Analysis of Tea (*Bamber*)

Essential oil	·05	per cent
Fixed oil	·50	,,
Theine	4·10	,,
Volatile Alkaloid	Trace	,,
Tannin	18·15	,,
Boheic Acid	2·38	,,
Gallic Acid	·83	,,
Legumen	24·00	,,
Albumin and Globulin	1·00	,,
Waxes and Gums	2·88	,,
Pectin, Pectoses, &c	12·60	,,
Amides	Trace	,,
Cellulose, Fibre, &c.	21·20	,,
Phlobaphene, Resins, &c	7·85	,,
Mineral Matter	4·50	,,
Moisture	Free	,,

BEHAVIOUR OF THEINE AND THEOBROMINE WITH REAGENTS (*Crole*).

Sulphomolybdic acid (Fröhde's) .	No reaction with theine, theobromine, and others.
Sulphovenadic acid . .	None with theine or nicotine.
Solution of I in KI . . .	None.
Mercuric chloride (saturated solution)	Abundant precipitate.
Sonnenschein's reagent . . .	Yellow, usually amorphous, precipitate (generally insoluble) with nearly all.
Scheibler's reagent . .	A very similar reaction.
Tannic acid . . .	Precipitates theine, theobromine, and colchicine.
Hager's reagent .	None with theine, theobromine, and several others.
Concentrated HCl. . .	None.
Pure concentrated H_2SO_4	Gives a faint straw-coloured tint with theine and others.
HNO_3 (sp. gr. 1·4) .	None If, however, theine is heated with a large excess of HNO_3, or if oxidised with chromic acid mixture, cholestrophane, or dimethyl-parabonic acid ($C^3(CH_3)_2N_2O_3$) is formed.

PROPERTIES OF THEINE OR CAFFEINE.

Pure theine or caffeine forms prisms of very pleasing silky appearance, which prisms are soluble in water, alcohol, and ether, and it is precipitated by tannin, and sublimated by heat. Its composition according to Garrod is ($C_{16}H_{10}N_4O_4+2HO$).

Taken internally theine or caffeine, or a strong solution containing it, is a tonic and stimulant which acts in a very powerful manner upon the nervous system, giving rise to great restlessness, heart palpitation, and other symptoms of a nervous character.

It likewise possesses, to a certain extent, the power of staying or arresting the changes or metamorphoses of the animal body, which is demonstrated by the decrease in the formation of urea caused by its use.

Theine and caffeine is employed for the relief of stupor due to the use of narcotics, in headaches of a nervous nature, to stop the paroxysms of spasmodic asthma, in whooping cough, and various forms of affections of an intermittent nature.

According to Huchard, caffeine can be administered internally in doses of from 2 to 6 grains. For hypodermic injection: 12 grains of caffeine with 15 grains of benzoate of sodium and 75 minims of distilled water. Tonic, stimulant, antithermic, regulates the cardiac functions; is given in all adynamic conditions.

Overdoses produce burning of the throat, excessive thirst, pains in the stomach and bowels, tremor of the extremities, vomiting, purging, and diuresis. Nitro-glycerine and apomorphine are said to be antidotes.

Adulteration of Tea with Foreign Leaves.

This description of adulteration can be the most readily detected by an examination under a microscope.

Indian Weights and Measures.

Weights.

North India.

Tola = 2 chitak, ·0125 seer, ·000313 maund, 0257 lb.
Chitak = 5 tola, ·0625 seer, ·00156 maund, ·12857 lb.
Seer = 80 tola, 16 chitak, ·025 maund, 2 0571 lbs.
Maund or Mau = 3,200 tola, 640 chitak, 40 seer, 82 2840 lbs.

Madras.

Tola = ·333 pollam, ·00833 vis, ·001042 maund, ·000521 candy, ·0257 lb
Pollam = 3 tola, ·025 vis, ·003125 maund, 0001563 candy, 07714 lbs.
Vis = 120 tola, 40 pollam, 125 maund, ·00615 candy, 3 0857 lbs
Maund or Mau = 960 tola, 320 pollam, 8 vis, ·05 candy, 24 686 lbs.
Candy = 19,200 tola, 6,400 pollam, 160 vis, 20 maund, 493 714 lbs.

Bombay.

Seer = 7 lb.; Maund = 28 lbs; Candy = 5 cwts.

Square Measure.

North India.	*Madras.*
Guj = ·111111, ·00028 biga, 84028 sq. yd	Kōl = ·04167 gūli, ·0004167 kāni, 24 sq. feet.
Baus = 9 guj, ·0025 biga, 7 5625 sq. yds	Gūli = 24 kol, ·010 kāni, 576 sq. feet.
Biga or Beegah = 3,600 guj, 400 baus, ·624 acre.	Kāni = 2,400 kōl, 100 guli, 1·32 acre.

Bombay.

Kati = ·05 paud, ·0025 biga, 10 sq. yds.
Paud = 20 kati, ·05 biga, 200 sq. yds.
Biga = 400 kati, 20 paud, ·825 acre.

Capacity.

North India.

Seer = 2 pali, ·025 maund, ·245 gallon.
Pali = 5 seer, ·125 maund, 1·226 gallons.
Maund = 40 seer, 8 pali, 9·81 gallons.

Madras.

Olak = ·08 padi, ·01 mercal, ·002 para, ·000025 gās, 8 cubic inches.
Padi = 12½ olak, ·125 mercal, ·025 para, ·0003175 gās, 100 cubic inches.
Mercal = 100 olak, 8 padi, 2 para, ·0025 gas, 800 cubic inches.
Para = 500 olak, 40 padi, 5 mercal, ·0125 gas, 4,000 cubic inches.
Gās = 40,000 olak, 3,200 padi, 400 mercal, 80 para, 1 gās, 185·2 cubic inches.

Bombay.

Seer = ·25 paili, ·015625 para, ·00195 candy, 49 cub ins., ·18 gallon.
Paili = 4 seer, ·0625 para, ·00781 candy, 197 cub ins., ·71 gallon.
Para = 64 seer, 16 paili, ·125 candy, 3,145 cub ins., 11·34 gallons.
Candy = 512 seer, 128 paili, 8 para, 25,160 cub ins., 90 74 gallons.

Length.

North India.

Jow = ·00694 guj, 0000017 kos, ·0229 ins
Guj = 144 jow, ·00025 kos, 33 ins
Kos = 576,000 jow, 4,000 guj, 2 08 miles

Madras.

Span = ·4444 cubit, ·0000556 kos, 8 ins.
Cubit = 2 25 span, ·000125 kos, 18 ins.
Kos = 18,000 span, 8,000 cubit, 2·27 miles.

Bombay.

Tasū = ·0625 hāth, ·04167 guj, 1 125 inch.
Hāth = 16 tasū, ·6667 guj, 18 inches.
Guj = 24 tasū, 1 5 hath, 27 inches.

Indian Money.

		Value, taking rupee at 1s. 4d.
1 pie	= . . .	$\frac{1}{12}$d.
3 „	= . . .	¼d.
11 „	= . . .	1d.
16 annas	= .	1s. 4d.
16 rupees	= .	£1 1s. 4d.
Lac (100,000 rupees)	= . . .	£6,666 13s. 4d.

Chinese Money.

1 tael
10 mace
100 conderin
1,000 cash
= 6s. 6¼d silver at 60⅜d. per troy oz.

Japanese Money.

10-yen piece = £2 0s. 11¾d.
1 yen of 100 sen. = 4s. 3¼d. silver at 60⅜d. per troy oz.

Table Showing Value of any Commodity, from 1 Seer to 1 Maund, at from 1 to 20 Rupees per Maund.

Seers.	At Rs. 1 per Maund.	At Rs. 2 per Maund.	At Rs. 3 per Maund.	At Rs. 4 per Maund.	At Rs. 5 per Maund	At Rs. 6 per Maund	At Rs. 7 per Maund.	At Rs. 8 per Maund.	At Rs. 9 per Maund	At Rs 10 per Maund.	At Rs. 15 per Maund.	At Rs. 20 per Maund.	Seers.
	R. A. P.	R A P	R. A. P	R A P.	R A P	R A. P.	R A P	R A. P.	R. A P	R. A. P	R A. P.	R A. P.	
1 ..	0 0 4	0 0 9	0 1 2	0 1 7	0 2 0	0 2 4	0 2 9	0 3 2	0 3 7	0 4 0	0 6 0	0 8 0	.. 1
2 ..	0 0 9	0 1 7	0 2 4	0 3 2	0 4 0	0 4 9	0 5 7	0 6 4	0 7 2	0 8 0	0 12 0	1 0 0	.. 2
3 ..	0 1 2	0 2 4	0 3 7	0 4 9	0 6 0	0 7 2	0 8 4	0 9 7	0 10 9	0 12 0	1 2 0	1 8 0	.. 3
4 ..	0 1 7	0 3 2	0 4 9	0 6 4	0 8 0	0 9 7	0 11 2	0 12 9	0 14 4	1 0 0	1 8 0	2 0 0	.. 4
5 ..	0 2 0	0 4 0	0 6 0	0 8 0	0 10 0	0 12 0	0 14 9	1 0 0	1 2 0	1 4 0	1 14 0	2 8 0	.. 5
6 ..	0 2 4	0 4 9	0 7 2	0 9 7	0 12 0	0 14 4	1 0 0	1 3 2	1 5 7	1 8 0	2 4 0	3 0 0	.. 6
7 ..	0 2 9	0 5 7	0 8 4	0 11 2	0 14 0	1 0 9	1 3 7	1 6 4	1 9 2	1 12 0	2 10 0	3 8 0	.. 7
8 ..	0 3 2	0 6 4	0 9 7	0 12 9	1 0 0	1 3 2	1 6 4	1 9 7	1 12 9	2 0 0	3 0 0	4 0 0	.. 8
9 ..	0 3 7	0 7 2	0 10 9	0 14 4	1 2 0	1 5 7	1 9 7	1 12 9	2 0 4	2 4 0	3 6 0	4 8 0	.. 9
10 ..	0 4 0	0 8 0	0 12 0	1 0 0	1 4 0	1 8 0	1 12 9	1 15 11	2 4 0	2 8 0	3 12 0	5 0 0	.. 10
11 ..	0 4 4	0 8 9	0 13 2	1 1 7	1 6 0	1 10 4	1 14 2	2 3 2	2 7 7	2 12 0	4 2 0	5 8 0	.. 11
12 ..	0 4 9	0 9 7	0 14 4	1 3 2	1 8 0	1 12 9	2 1 7	2 6 4	2 11 2	3 0 0	4 8 0	6 0 0	.. 12
13 ..	0 5 2	0 10 4	0 15 7	1 4 9	1 10 0	1 15 2	2 4 4	2 9 7	2 14 9	3 4 0	4 14 0	6 8 0	.. 13
14 ..	0 5 7	0 11 2	1 0 9	1 6 4	1 12 0	2 1 7	2 7 2	2 12 9	3 2 4	3 8 0	5 4 0	7 0 0	.. 14
15 ..	0 6 0	0 12 0	1 2 0	1 8 0	1 14 0	2 4 0	2 10 0	3 0 0	3 6 0	3 12 0	5 10 0	7 8 0	.. 15
16 ..	0 6 4	0 12 9	1 3 2	1 9 7	2 0 0	2 6 4	2 12 9	3 3 2	3 9 7	4 0 0	6 0 0	8 0 0	.. 16
17 ..	0 6 9	0 13 7	1 4 4	1 11 2	2 2 0	2 8 9	2 15 7	3 6 4	3 13 2	4 4 0	6 6 0	8 8 0	.. 17
18 ..	0 7 2	0 14 4	1 5 7	1 12 9	2 4 0	2 11 2	3 2 4	3 9 7	4 0 9	4 8 0	6 12 0	9 0 0	.. 18
19 ..	0 7 7	0 15 2	1 6 9	1 14 4	2 6 0	2 13 7	3 5 2	3 12 9	4 4 4	4 12 0	7 2 0	9 8 0	.. 19
20 ..	0 8 0	1 2 0	1 8 0	2 0 0	2 8 0	3 0 0	3 8 0	4 0 0	4 8 0	5 0 0	7 8 0	10 0 0	.. 20
25 ..	0 10 0	1 4 0	1 14 0	2 8 0	3 2 0	3 12 0	4 6 0	5 0 0	5 10 0	6 4 0	9 6 0	12 8 0	.. 25
30 ..	0 12 0	1 8 0	2 4 0	3 0 0	3 12 0	4 8 0	5 4 0	6 0 0	6 12 0	7 8 0	11 4 0	15 0 0	.. 30
35 ..	0 14 0	1 12 0	2 10 0	3 8 0	4 6 0	5 4 0	6 2 0	7 0 0	7 14 0	8 12 0	13 2 0	17 8 0	.. 35
40 ..	1 0 0	2 0 0	3 0 0	4 0 0	5 0 0	6 0 0	7 0 0	8 0 0	9 0 0	10 0 0	15 0 0	20 0 0	.. 40

TABLE SHOWING THE VALUE OF ANY QUANTITY OR NUMBER OF GOODS OR WARES, FROM 1 TO 1,000, AT FROM 1 ANNA TO 10 RUPEES EACH.

e.	At 1 Anna each.	At 2 Annas each.	At 3 Annas each.	At 4 Annas each.	At 5 Annas each.	At 6 Annas each.	At 8 Annas each.	At 12 Annas each.	At 1 Rupee each.	At 2 Rupees each.	At 3 Rupees each	At 4 Rupees each.	At 5 Rupees each.	At 6 Rupees each.	At 7 Rupees each.	At 8 Rupees each.	At 9 Rupees each.	At 10 Rupees each.
	R. A.	R. A.	R. A.	R. A	R A.	R. A	R A	R. A	R	R.	R	R.	R.	R.	R.	R.	R.	R.
1	0 1	0 2	0 3	0 4	0 5	0 6	0 8	0 12	1	2	3	4	5	6	7	8	9	10
2	0 2	0 4	0 6	0 8	0 10	0 12	1 0	1 8	2	4	6	8	10	12	14	16	18	20
3	0 3	0 6	0 9	0 12	0 15	1 2	1 8	2 4	3	6	9	12	15	18	21	24	27	30
4	0 4	0 8	0 12	1 0	1 4	1 8	2 0	3 0	4	8	12	16	20	24	28	32	36	40
5	0 5	0 10	0 15	1 4	1 9	1 14	2 8	3 12	5	10	15	20	25	30	35	40	45	50
	0 6	0 12	1 2	1 8	1 14	2 4	3 0	4 8	6	12	18	24	30	36	42	48	54	60
7	0 7	0 14	1 5	1 12	2 3	2 10	3 8	5 4	7	14	21	28	35	42	49	56	63	70
	0 8	1 0	1 8	2 0	2 8	3 0	4 0	6 0	8	16	24	32	40	48	56	64	72	80
	0 9	1 2	1 11	2 4	2 13	3 6	4 8	6 12	9	18	27	36	45	54	63	72	81	90
	0 10	1 4	1 14	2 8	3 2	3 12	5 0	7 8	10	20	30	40	50	60	70	80	90	100
	1 4	2 8	3 12	5 0	6 4	7 8	10 0	15 0	20	40	60	80	100	120	140	160	180	200
	1 14	3 12	5 10	7 8	9 6	11 4	15 0	22 8	30	60	90	120	150	180	210	240	270	300
	2 8	5 0	7 8	10 0	12 8	15 0	20 0	30 0	40	80	120	160	200	240	240	320	360	400
	3 2	6 4	9 6	12 8	15 10	18 12	25 0	37 8	50	100	150	200	250	300	350	400	450	500
	3 12	7 8	11 4	15 0	18 12	22 8	30 0	45 0	60	120	180	240	300	360	420	480	540	600
	4 6	8 12	13 2	17 8	21 14	26 4	35 0	52 8	70	140	210	280	350	420	490	560	630	700
	5 0	10 0	15 0	20 0	25 0	30 0	40 0	60 0	80	160	240	320	400	480	560	640	720	800
	5 10	11 4	16 14	22 8	28 2	33 12	45 0	67 8	90	180	270	360	450	540	630	720	810	900
	6 4	12 8	18 12	25 0	31 4	37 8	50 0	75 0	100	200	300	400	500	600	700	800	900	1000
	12 8	25 0	37 8	50 0	62 8	75 8	100 0	150 0	200	400	600	800	1000	1200	1400	1600	1800	2000
	18 12	37 8	56 4	75 0	93 12	112 8	150 0	225 0	300	600	900	1200	1500	1800	2100	2400	2700	3000
	25 0	59 0	75 0	100 0	125 0	150 0	200 0	300 0	400	800	1200	1600	2000	2400	2800	3200	3600	4000
	31 4	62 8	93 12	125 0	156 4	187 8	250 0	375 0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
	37 8	75 9	112 8	150 0	187 8	225 0	300 0	450 0	600	1200	1800	2400	3000	3600	4200	4800	5400	6000
	43 12	87 8	131 4	175 0	218 12	262 8	350 0	525 0	700	1400	2100	2800	3500	4200	4900	5600	6300	7000
	50 0	100 0	150 0	200 0	250 0	300 0	400 0	600 0	800	1600	2400	3200	4000	4800	5600	6400	7200	8000
	56 4	112 8	168 12	225 0	281 4	337 8	450 0	675 0	900	1800	2700	3600	4500	5400	6300	7200	8100	9000
	62 8	125 0	187 8	250 0	312 8	375 0	500 0	750 0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000

THE PRICE PER MAUND IN RUPEES, ANNAS OR PIES, EQUAL TO RUPEES PER TON.

Per Ton. R.	A.	P.	Per Maund. In Rupees.	In Annas.	In Pies.
0	0	1	0002	0031	037
0	0	2	0004	·0062	·074
0	0	3	0006	0092	110
0	0	4	·0008	0123	·147
0	0	5	0010	0153	184
0	0	6	0012	·0192	221
0	0	7	0013	0214	·258
0	0	8	·0015	·0245	294
0	0	9	0017	0276	331
0	0	10	0019	0306	368
0	0	11	0021	·0337	·405
0	1	0	0023	0368	442
0	2	0	·0046	·0735	88
0	3	0	0069	1103	1 32
0	4	0	0092	1471	1·76
0	5	0	·0115	1838	2 21
0	6	0	0138	2206	2·65
0	7	0	0161	2573	3 09
0	8	0	018	29	3 53
0	9	0	020	33	3 97
0	10	0	023	36	4·41
0	11	0	025	·40	4·85
0	12	0	028	·44	5·30
0	13	0	·030	·48	5·74
0	14	0	032	52	6 18
0	15	0	·035	·55	6·62
1	0	0	·037	·59	7·06
2	0	0	·074	1·18	14 1
3	0	0	110	1·76	21·2
4	0	0	147	2 35	28 2
5	0	0	·184	2 94	35·3
6	0	0	·221	3 53	42·4
7	0	0	257	4·12	49 4
8	0	0	294	4 71	56·5
9	0	0	331	5 30	63·5
10	0	0	368	5 88	70 6

Weight Calculating Table.

English Weight Converted into Factory and Bazaar Weights.

English Weight.				Factory Weight.				Bazaar Weight.			
Tons	cwts.	qrs.	lbs.	Mds.	sr.	ck.	Dec.	Mds.	sr.	ck.	Dec.
1000	0	0	0	30,000	0	0	..	27,272	29	1	45
500	0	0	0	15,000	0	0	..	13,636	14	8	72
200	0	0	0	6,000	0	0	..	5,454	21	13	09
100	0	0	0	3,000	0	0	..	2,727	10	14	54
80	0	0	0	2,400	0	0	..	2,181	32	11	63
60	0	0	0	1,800	0	0	..	1,636	14	8	72
40	0	0	0	1,200	0	0	..	1,090	36	5	81
20	0	0	0	600	0	0	..	545	18	2	90
10	0	0	0	300	0	0	..	272	29	1	45
9	0	0	0	270	0	0	..	245	18	2	90
8	0	0	0	240	0	0	..	218	7	4	36
7	0	0	0	210	0	0	..	190	36	5	81
6	0	0	0	180	0	0	..	163	25	7	27
5	0	0	0	150	0	0	..	136	14	8	72
4	0	0	0	120	0	0	..	109	3	10	18
3	0	0	0	90	0	0	..	81	32	11	63
2	0	0	0	60	0	0	..	54	21	13	09
1	0	0	0	30	0	0	..	27	10	14	54
0	10	0	0	15	0	0	..	13	25	7	27
0	8	0	0	12	0	0	..	10	36	5	81
0	6	0	0	9	0	0	..	8	7	4	36
0	4	0	0	6	0	0	..	5	18	2	90
0	2	0	0	3	0	0	..	2	29	1	45
0	1	0	0	1	20	0	..	1	14	8	72
0	0	2	0	0	30	0	..	0	27	4	36
0	0	1	0	0	15	0	..	0	13	10	18
0	0	0	1	0	0	8	57	0	0	7	79

Table of Daily Pay or Allowance.

Rupees per Month	Of 28 Days.			Of 29 Days.			Of 30 Days.			Of 31 Days.			Rupees per Month.	Of 28 Days.			Of 29 Days.			Of 30 Days.			Of 31 Days.		
R.	R.	A.	P.	R.	A.	P.	R.	A.	P.	R.	A.	P.	R	R.	A.	P.	R.	A.	P.	R.	A.	P.	R.	A.	P.
1	0	0	6	0	0	6	0	0	6	0	0	6	200	7	2	3	6	14	4	6	10	8	6	7	2
2	0	1	1	0	1	1	0	1	1	0	1	0	300	10	11	5	10	5	6	10	0	0	9	10	10
3	0	1	8	0	1	7	0	1	7	0	1	6	400	14	4	6	13	12	8	13	5	4	12	14	5
4	0	2	3	0	2	2	0	2	1	0	2	0	500	17	13	8	17	3	10	16	10	8	16	2	0
5	0	2	10	0	2	9	0	2	8	0	2	6	600	21	6	10	20	11	0	20	0	0	19	5	8
6	0	3	5	0	3	3	0	3	2	0	3	1	700	25	0	0	24	2	2	23	5	4	22	9	3
7	0	4	0	0	3	10	0	3	8	0	3	7	800	28	9	1	27	9	4	26	10	8	25	12	10
8	0	4	6	0	4	4	0	4	3	0	4	1	900	32	2	3	31	0	6	30	0	0	29	0	6
9	0	5	1	0	4	11	0	4	9	0	4	7	1,000	35	11	5	34	7	8	33	5	4	32	4	1
10	0	5	8	0	5	6	0	5	4	0	5	1	2,000	71	6	10	68	15	5	66	10	8	64	8	3
20	0	11	5	0	11	0	0	10	8	0	10	3	3,000	107	2	3	103	7	2	100	0	0	96	12	4
30	1	1	1	1	0	6	1	0	0	0	15	5	4,000	142	13	8	137	14	10	133	5	4	129	0	6
40	1	6	10	1	6	0	1	5	4	1	4	7	5,000	178	9	1	172	6	7	166	10	8	161	4	7
50	1	12	6	1	11	7	1	10	8	1	9	9	6,000	214	4	0	206	14	4	200	0	0	193	8	9
60	2	2	3	2	1	1	2	0	0	1	14	11	7,000	250	0	0	241	6	1	233	5	4	225	12	11
70	2	8	0	2	6	7	2	5	4	2	4	1	8,000	285	11	5	275	13	10	266	10	8	258	1	0
80	2	13	8	2	12	1	2	10	8	2	9	3	9,000	321	6	10	310	5	6	300	0	0	290	5	3
90	3	3	5	3	1	7	3	0	0	2	14	5	10,000	357	2	3	344	13	2	333	5	4	322	9	3
100	3	9	1	3	7	2	3	5	4	3	3	7													

Particulars required to estimate for an Aërial Tramway.

(1) Length of line. (2) In case the line does not go straight from end to end; then, the number and degrees of angles. (3) An approximate section of the ground to be passed over. (4) Quantity of material to be carried per hour. (5) What power is available for driving. (6) Whether or not suitable timber can be procured on the spot for the construction of terminal frames and posts.

Estimate for Light Line of Aërial Tramway (W. R. Shaw, M.E.).

The following description and estimate taken from the "Indian and Eastern Engineer" of a very light line on the continuous running rope system will be useful to planters:—100 feet rise or fall per mile will make little appreciable difference in the driving power required, only about ⅛ h.-p. per mile. The line can be of any length, but long lines must be divided into sections, and no section must be more than 3 miles. Two sections can be coupled together and driven by the same source of power.

Line to deliver 20 maunds per hour in loads not exceeding 2 maunds each.

Steel rope 1¾ inch circumference, weight per fathom 2 lbs., guaranteed breaking strain 5½ tons, price at home 2½ pence per foot, will be used.

Speed 2½ miles per hour, 10 loads per hour; loads will be 1,450 feet apart.

The driving power required will be about 2 h.-p. per mile. The power can be taken off an engine or turbine, or failing these, the line can be driven by bullocks working on a Persian wheel geared to one end of the line. If power is available, the line can carry two or three times as many loads as are taken. Spans will usually be 200 feet, but occasional spans can be as much as 500 feet.

Estimate for all materials except woodwork, line 3 miles long, delivering 20 maunds per hour.

	Rs.
Rope, 6 miles at 39 annas per foot	6,957
Carriers, 21 at Rs. 50	1,050
Pulleys, 6 inches diameter, 150 at Rs. 10 ...	1,500
End pulleys, 4 feet diameter, 2 at Rs 250 ...	500
Fittings for terminals and counter-weight ...	100
	10,107
Contingencies 5 per cent	505
TOTAL ...	10,612

Say Rs. 11,000.

Assuming there is a source of power available, the working expenses will be :—

	Rs.	A.	P.
4 coolies loading and unloading at 6 annas ...	1	8	0
Oiling and supervision	1	0	0
TOTAL ...	2	8	0

Output, 20 maunds × 8 hours — 160 maunds.

This works out three pies per maund per mile exclusive of repairs and renewals. When a *pucca* cart road has been made, a wire tramway of this kind would not be of much use, but there are lots of gardens which have to depend on a *kutcha* road and where a line of this kind would soon pay for itself.

TABLE OF WORKING STRENGTH OF ROPES IN TONS.

Circum. Inches.	Hemp.		Wire.		Circum. Inches.	Hemp.	
	Common.	Good.	Iron.	Steel.		Common.	Good.
1	032	·046	29	·45	4¼	578	·831
1¼	·050	·072	·45	·70	4½	·648	·932
1½	·072	·104	·65	1·01	4¾	·722	1·038
1¾	·098	·141	89	1 38	5	800	1 150
2	·128	·184	1·16	1·80	5½	·968	1·392
2¼	·162	·233	1 47	2·28	6	1·152	1·656
2½	·200	·288	1 81	2 81	6½	1·352	1 944
2¾	·242	·348	2·19	3 40	7	1·568	2·254
3	·288	·414	2 61	4·05	7½	1·800	2·588
3¼	·338	·486	3·06	4 75	8	2·048	2·944
3½	·392	·564	3 55	5 51	8½	2 312	3·324
3¾	450	·647	4 08	6·33	9	2.592	3·726
4	·512	·736	4·64	7·20	10	3·200	4·600

Single Line Tramway.

The single-rail tramway invented by Mr. Charles Ewing has been adopted on some Indian plantations, and appears very suitable for countries possessing good roads. A single line of rail, weighing about 14 lbs. to the yard, is laid upon a level road; on the rail run the trucks, which are mounted on double-flanged wheels placed under the centre. Support is given on one side of the truck by a light iron balance wheel running on an axle which is kept in position by a horn plate fixed to the frame of the truck. A double-helical spring fitted to the axle prevents excessive jolting when the balance wheel encounters inequalities in the road surface. The trucks, which are 8 feet or 9 feet wide, are made of planks of teak or other suitable wood fastened with nuts and bolts, and, in parts of India, are drawn by bullocks.

INDEX.

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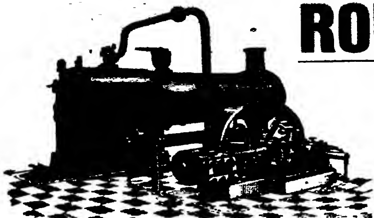
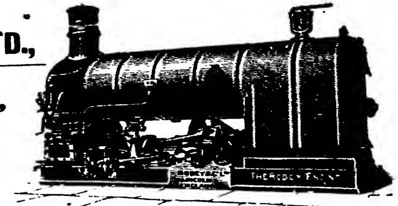
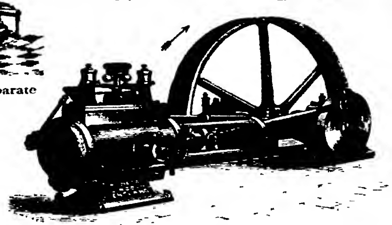


Medium Stroke Horizontal Engines, with separate Locomotive Boiler.



The Original "Robey" Undertype Compound Engine, with Automatic Expansion Gear.

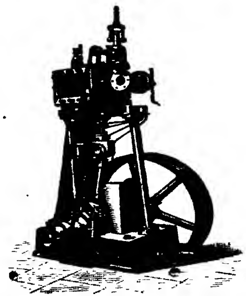


Horizontal Fixed Engines, with Patent Trip Expansion Gear.

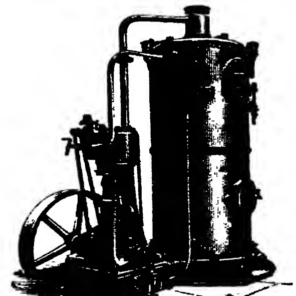
* ILLUSTRATED CATALOGUE SENT FREE ON APPLICATION. *

* * *

N.B.—Upwards of 20,000 Engines at work in all parts of the World.



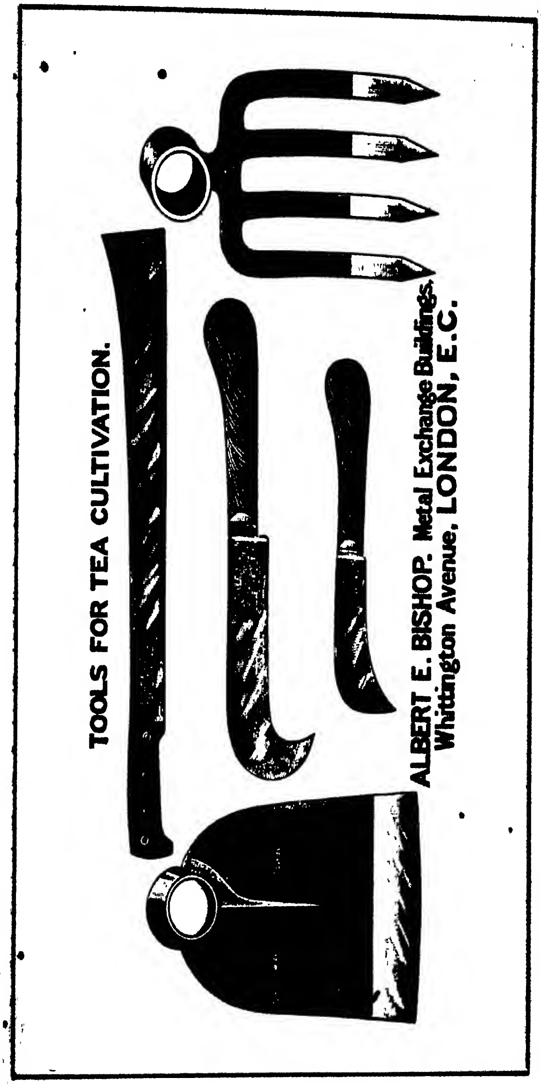
High Speed Electric Light Engines.



Vertical Engine and Boiler.

London Office and Showroom:

79, QUEEN VICTORIA STREET.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